



BIM implementations in Mega-projects

“BIM influence on Mega-project management”

Master thesis

International Master of Science in Construction and Real Estate Management

Joint Study Program of Metropolia UAS and HTW Berlin

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Mohamed Elkhedr Haseeb Elkhedr

Registration number: S0557600

First Supervisor: Sunil Suwal

Second Supervisor: Prof. Dr.-Ing. Markus Krämer

[Acknowledgment]

.....

"Never forget that you are an engineer" Prof. Osama Kamal, 2008.

The most appreciated sentence that I had learned during my educational journey.

This sentence supported me in the most critical situation through my career and led me to the success path, regardless the circumstances.

I would like to thank prof. Osama Kamal and the whole team of Shoubra faculty of engineering for their support and help during my bachelor degree. Although we didn't have the best utilities, they tried their best to keep the quality of the educational process.

As well I would like to thank the teams of Metropolia UAS & HTW Berlin for the whole time I spent in both universities and also thanks to all my classmates in ConREM for the time that we spent together in this program.

The major part of my inspiration to write about Mega-projects is Prof. Bent Flyvbjerg's publications in this field. It is a huge addition to both the academic and professional fields in the sector of Mega-projects Management.

Finally, during my studies in ConREM, sadly, my father passed away, which caused me a real deep painful feelings, I hope that his soul is resting in peace and God forgive him everything in his life.

Who, when disaster strikes them, say, "Indeed we belong to Allah, and indeed to Him we will return." Quran 2:156.

International Master of Science in Construction and Real Estate Management
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Conceptual Formulation

Master Thesis for Mr. Mohamed Elkhedr Haseeb Elkhedr

Student number S0557600

Topic: BIM implementations in Mega projects

Introduction

Recent studies show that despite their growing popularity, megaprojects – large-scale, complex projects delivered through various partnerships between public and private organizations – often fail to meet costs estimations, time schedules and project outcomes and are motivated by vested interests which operate against the public interest.

Megaprojects (sometimes also spelled "mega projects") are very large investment projects. The US Federal Highway Administration defines megaprojects as major infrastructure projects that cost more than US\$1 billion, or projects of a significant cost that attract a high level of public attention or political interest because of substantial direct and indirect impacts on the community, environment, and budgets. Some megaprojects, like Boston's Big Dig at \$15 billion or the Channel tunnel between France and the UK at \$10 billion, cost several times this minimum definition of a megaproject. Other projects that cost less than \$1 billion are sometimes also called megaprojects; it depends on the context, because a, say, \$500 million project in a medium-sized town may be considered "mega," whereas this would not necessarily be the case for a similar-sized project in a major world city.

"Mega" also implies the size of the task involved in developing, planning, and managing projects of this magnitude. The risks are substantial. Cost overruns of 50% are common, overruns of 100% is not uncommon. Similarly, substantial benefit shortfalls trouble many megaprojects. Finally, regional development effects and environmental impacts often turn out very differently, from what proponents promised. Cost overruns combined with benefit shortfalls spell trouble. However, an interesting paradox exists for megaprojects: more and bigger megaprojects are being planned and built despite their poor performance record in terms of costs and benefits.

“BIM” Building information modeling based solutions are actively implemented in the AEC/FM projects with positive results on cost and time-savings. These type of solutions have huge potential to mitigate various problems that can happen through the project phases although it would cost much more in the case of megaprojects where huge amount of data are needed to be filtered and processed. If a future view is available, it will give the chance to predict problems, experiment different solutions and avoid fatal disasters in the case of large investments and high importance projects.

Research Methods

- Case Studies

A case study will be included in the master thesis, and on each stage or phase, some professional examples would be mentioned and explained to clarify the ideas that the author wants to deliver.

- Questionnaires

The following questionnaires would be submitted to professionals and experts in AEC industry specially who had been involved in Mega projects and realized the real effect of BIM implementations in Mega project.

- What role do you perform currently within your organization?
- What is your organization behalf in projects (Client – Contractor – Consultant – Third party)?
- In which countries does your organization carry out projects?
- What is the major sector of your organization projects?
- What is the average project value range your organization is involved in?
- Does your organization currently use BIM, is it planning to use BIM in the future, and how long have been your organization using BIM?
- "BIM is essential tool to manage a Mega project" how far do you agree with this statement?
- What do you think about the key benefits of BIM in a Mega project, in terms of: (feasibility studies & kick off decision – Cost reduction – Errors reduction – Risk reduction)?
- Through your professional experience, what was the situation that you realize the serious need or effect BIM in AEC industry?
- How do you imagine that BIM can take a full control for a Mega project life cycle?
- How BIM can be used for facility management?
- Do you think that BIM can help to dismantle a Mega project?

Most of the previous questionnaires will be in both quantitative and qualitative phases according to the population, and the author undertakes that the collective data will be used only for academic proposes.

- Interviews

Interviews will be mainly through BIM-Arabia magazine

<http://bimarabia.com/bimarabia-english/>

BIMarabia is the first E-magazine intended to spread awareness of BIM tools and workflows across Arabic region. BIMarabia is written and edited by users, targeted to be beneficial to practitioners and researchers in the field.

- Internet research

Searching for pervious academic researchers in similar topic, also contact with companies that are involved in Mega projects to collect practical information to assist the thesis findings.

Research Questions

For Mega projects, throughout the whole project phases, BIM had made a huge difference and has been an advantage, but still has not been involved at some point on each project phase; the following research questions will give a better understanding for the differences between ordinary projects and Mega projects, also BIM fingerprint at each stage of the Mega project.

- What are the definitions of Mega project and BIM in AEC industry?
- How BIM can assist the required feasibility studies that can assist the kick off decisions?
- What are the initial plan and the design development required?
- Why BIM is an essential tool to deliver a Mega project?
- What are the key benefits of BIM in a Mega project, in terms of: (feasibility studies & kick off decision – Cost reduction – Errors reduction – Risk reduction)?
- Can BIM be implemented at any stage of a Mega project even if it was not from the beginning?
- How BIM can be valuable for a Mega project stakeholders & top management?
- What are BIM abilities to predict upcoming risks in Mega projects?
- How can BIM be used for dismantling a Mega project?

Possible Results

Mega projects life cycle analysis and find out the necessary recommendations for each phase, studying the effect of BIM at each phase to find out how it can be developed in future to get the best benefits of this technology.

Analysis the common risks that faced the previous mega projects and find out the necessary recommendations to avoid it in future or suggest alternative scenarios to mitigate it.

Schedule

Activity Month	2017							2018					
	Feb.	Mar.	Apr.	May	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	
Thesis Proposal	█												
Internet research	█												
Collecting quantitative data					█								
Collecting qualitative data + interviews					█								
Case study						█							
Results								█					
Revision											█		



Signature of the Supervisor, signed 13.01.2018

Sunil Suwal
 Lecturer, Construction and Real Estate Management
 Metropolia University of Applied Sciences,
 Helsinki, Finland
 sunil.suwal@metropolia.fi

Abstract

This paper is illustrating the development of BIM impact on the life cycle of Mega-projects. Historically Mega-projects have an economic relationship with national or global financial crisis and the success of this type of projects can make major changes to a country or a group of countries. For this point of view, this type of projects deserves to be highlighted and spotted to find out the circumstances and problems leads to failure or success in this type of projects. As well BIM is a quite new tool in the AEC industry and has its positive influence on the project whole live cycle that opens new visions to the industry.

This study will try to measure the influence that BIM has to Mega-projects in its different stages and evaluate this influence or discover some weaknesses which were not highlighted before. And the study will be built by transferring the experience from the field of the industry to the academic field.

Most of BIM benefits have a positive influence to Mega-projects common problems. However, there are some problems are not connected to the technology or to the tools used to deliver the project. The findings are concluding the major and minor influences of BIM in the mega-project life cycle.

- Keywords: Mega-projects, Mega-projects common problems, Building Information Modeling, BIM or not?, Project Control Systems, BIM & life cycle, BIM benefits, Systems Coordination, BIM Influence to Project life cycle.

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List of Abbreviations

AEC	Architecture, Engineering, Construction
AIA	American Institute of Architecture
BIM	Building Information Modeling
CAD	Computer Aided Design
CM@R	Construction management at risk
DBB	Design Bid Build
FIC	Facility Information Council
ICT	Information and communication technology
IFC	Industry Foundation Classes
IPD	Integrated project delivery
GMP	Guaranteed Maximum Price
NBIMS	National Building Information Modeling Standard
NIBS	Committee of the National Institute of Building Sciences
PEP	Project Execution Plan
ROI	Return of Investment
SMEs	Small and medium sized enterprises
UK	United Kingdom
UKOGC	United Kingdom's Office of Government Commerce
US	United States
US dollar	United States dollar
USA	United States of America
USD	United States Dollar

List of Symbols

\$ United States of America currency (US Dollar)

% Percent.

1 . Introduction

1.1 General

All over the world, there are those projects that take a huge budget and for many years to be delivered, recent studies show that despite their growing popularity, megaprojects – large-scale, complex projects delivered through various partnerships between public and private organizations – often fail to meet costs estimations, time, and project outcomes and are motivated by vested interests which operate against the public interest.

Megaprojects (sometimes also spelled "mega-projects") are very large investment projects. The US Federal Highway Administration defines megaprojects as major infrastructure projects that cost more than US\$1 billion, or projects of a significant cost that attracts a high level of public attention or political interest because of substantial direct and indirect impacts on the community, environment, and budgets. Some megaprojects, like Boston's Big Dig at \$15 billion or the Channel tunnel between France and the UK at \$10 billion, cost several times this minimum definition of a megaproject. Other projects that cost less than \$1 billion are sometimes also called megaprojects; it depends on the context, because a, say, \$500 million project in a medium-sized town may be considered "mega," whereas this would not necessarily be the case for a similar-sized project in a major world city.

"Mega" also implies the size of the task involved in developing, planning, and managing projects of this magnitude. The risks are substantial. Cost overruns of 50% are common, overruns of 100% not uncommon. Similarly, substantial benefit shortfalls trouble many mega projects. Finally, regional development effects and environmental impacts often turn out very differently from what proponents promised. Cost overruns combined with benefit shortfalls spell trouble. But an interesting paradox exists for megaprojects: More and bigger megaprojects are being planned and built despite their poor performance record in terms of costs and benefits.

As “BIM” Building information modeling based solutions are developing through the AEC industry, though it is highly needed to implement those solutions to large investment projects to mitigate various problems that can happen through the project phases, which will cost much more in the case of megaprojects where huge amount of data should be filtered and processed. If a future view is available, it will give the chance to predict problems, experiment with different solutions and avoid fatal disasters in the case of large investments and high importance projects.

BIM benefits will be divided by phase and the main stakeholders with higher influence to the project in each phase as follows:

- Owner benefits (Owner, Architects) (Design development phase).
- Design benefits (Owner, Planners, Designers, and Architects) (Detailed design phase).
- Construction and Fabrication Benefits. (Contractors) (Construction phase).
- Post construction phase (Facility managers, Users, Owner ...)

1.2 Problem Statement

Mega-projects can boom the economy of a country or further the world economy itself, for example, Yiwu - Madrid Railway line. Mega-projects are so attractive to decision makers on a national or global scale and there are main magnificent factors that makes Mega-projects attractive even if it is related historically to the financial crisis, these magnificent factors are called "four sublimes" of megaproject management:

- Political
- Technological
- Economic
- Aesthetic

In this research, those four sublimines and the following characteristics of megaprojects will be discussed and connected to BIM benefits to find out the impact and influence of BIM benefits to each problem and phase, those characteristics of megaprojects are also common with fewer scale projects, however in Mega-projects it is more likely to take place through the project life cycle.

- Complexity of Megaprojects
- Project team changes
- Multi Stakeholders
- Uniqueness bias
- Fail slow
- Rent seeking
- Change in project scope
- High risk delivery
- Inadequate budget and time.
- Misinformation

1.3 Research Objectives

- To find out If BIM is an essential tool to deliver a mega-project? And why?
- Evaluate the impact of BIM benefits and measure its influence on the common Mega-projects problems.
- What is the value of using BIM from the early stage of the project and Can BIM implemented at any stage of the Mega-project? And why?

1.4 Methodology

The following steps shall be applied in the thesis to achieve our objectives:

- Conduct a literature review which defines the Mega-projects, its value and influence, its characteristics and the common problems. Also BIM, its application procedures, processes and its benefits.
- Creating a Matrix between the Mega-projects problems and the BIM benefits in each phase. Then using this Matrix to evaluate the influence of each benefit to each problem.
- Develop questionnaires to identify the influence of each benefit to each problem and to evaluate these influences as the 1st stage of evaluation.
- Analyze the data from the questionnaires which highlight the influence of each benefit on each problem.
- Conduct interviews with experts in BIM who are already working in Mega-projects to validate the outcomes of the questionnaires.
- The feedback and the outcome of the interviews will supersede the feedback of the questionnaires in case of conflicts.

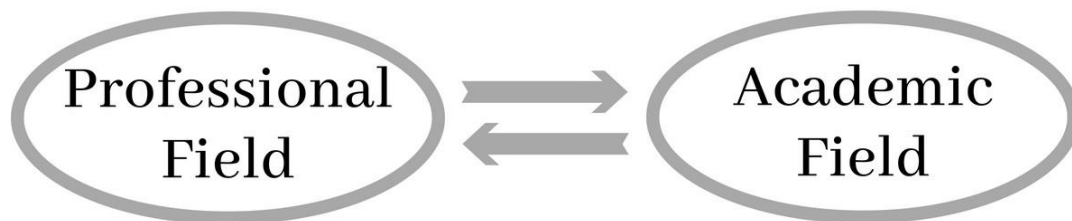


Figure 1 Knowledge exchange between Professional field and academic field

1.5 Research flow chart

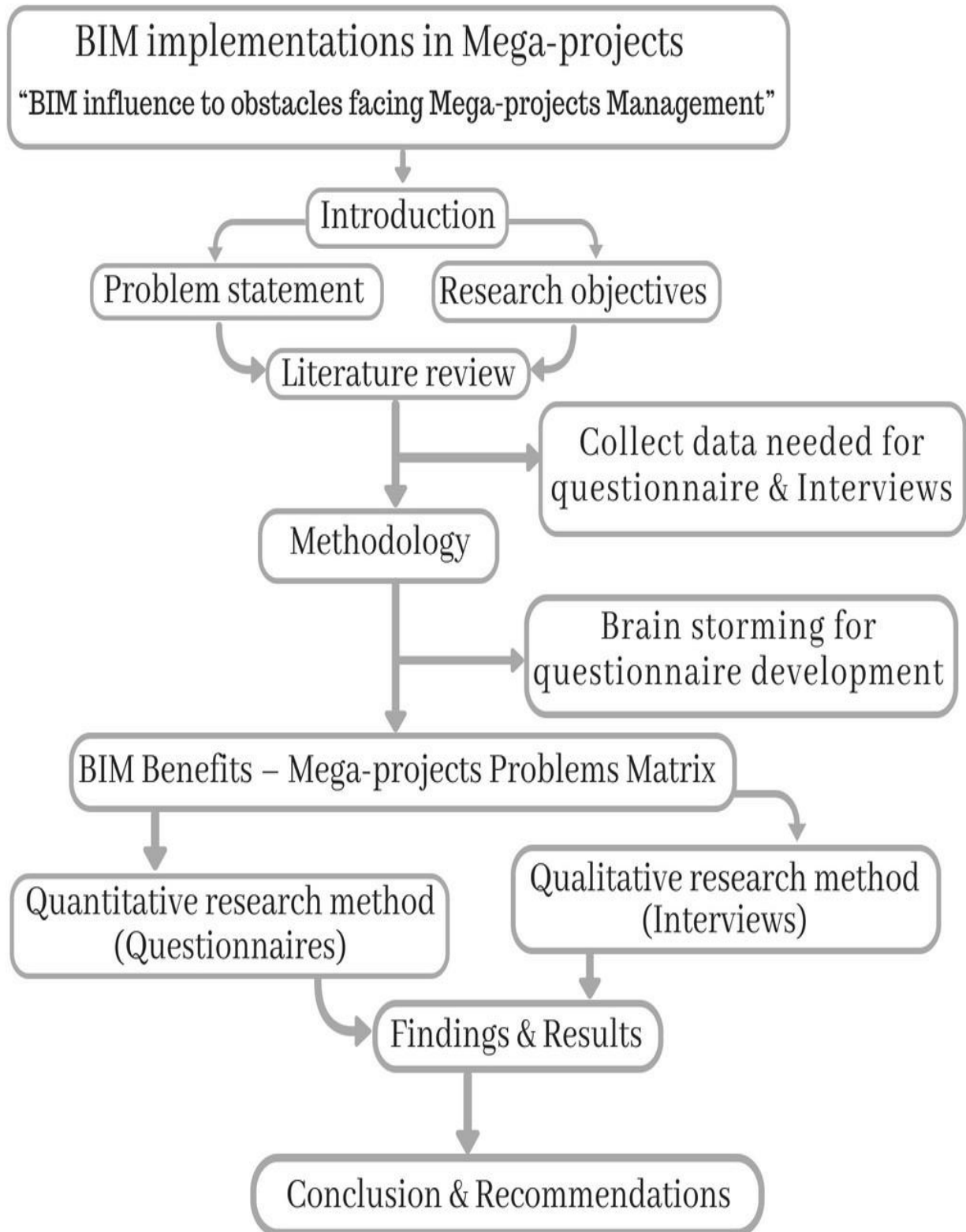


Figure 2 Research flow chart

2 . Literature review

2.1 Mega-Project overview

2.1.1 Megaprojects in terms of size.

“Megaprojects are large-scale, complex ventures that typically cost a billion dollars or more, take many years to develop and build, involve multiple public and private stakeholders, are transformational, and impact millions of people.” (Hirschman, 1995, P.7).

Generally, If Projects are identified by a budget scale, it will be:

- Mega-projects are measured in billions of dollars. [$> 1,000,000,000$ USD]
- Major projects in hundreds of millions. [$<1,000,000,000 - >100,000,000$ USD]
- Projects in millions and tens of millions. [$<100,000,000$ USD]

Megaprojects in some cases also called "major programs." calls such projects "privileged particles of the development process" as it is a special case of development like a pulse forward and points out that often they are "trait making" "Land Marks" that is, they are designed willing to change the structure of society, on the other side smaller and more conventional projects that are "trait taking", they fit into pre-existing structures and do not attempt to modify these.

Therefore, Mega-projects are not just larger or greater versions of smaller projects. Megaprojects are a totally different type of projects in terms of their level of aspiration, lead times, complexity, and stakeholder involvement. Furthermore, Mega-projects are also a very different type of project to manage. (Flyvbjerg, 2014, p. 4)

“If managers of conventional projects need the equivalent of a driver's license to do what they do then managers of megaprojects need a pilot's jumbo jet license” (O'Connell, 2014), (Flyvbjerg, 2014, p. 4).

Moreover, as long as, it is would not smart to ask someone with only a driver's license to fly a jumbo, it should not be expected that conventional project managers to manage megaprojects.

Megaprojects are used progressively as the preferred delivery model for goods and services across a range of businesses and sectors such as:

- Infrastructure
- Water and Energy
- Information Technology
- Industrial processing plants and Mining.
- Supply chains, enterprise systems, strategic corporate initiatives and change programs.
- Government administrative systems and banking.
- Defense, intelligence, air and space exploration.
- Big Science, Urban regeneration, and Major events.

Examples of megaprojects:

- High-speed rail lines, Airports, Seaports, and Motorways.
- Hospitals, National health, Pension ICT systems and National broadband
- The Olympics, large-scale signature architecture
- Dams, Wind farms.
- Offshore oil and gas extraction.
- Aluminum smelters.
- Development of new aircraft, the largest container and cruise ships.
- Logistics systems used to run large supply-chain-based companies like Amazon.

For a furthered explanation of how big megaprojects are, and to give a clearer picture about the type and the size of projects meant, it can be compared to one of the biggest numbers that can be measured in the economy as the size of US debt to China. This debt is about one trillion US dollars and is considered so large it may affect the stability of the world economy if the debt is not managed wisely. With this supersize measuring scale, with a comparison which considers that the combined cost of only two of the world's largest megaprojects:

Joint Strike Fighter aircraft program + China's high-speed rail project = more than half of this figure, at 700 billion dollars, as shown in the following figure.

The cost of the largest megaprojects in the world will lessen nearly any other economic or any investment figure.

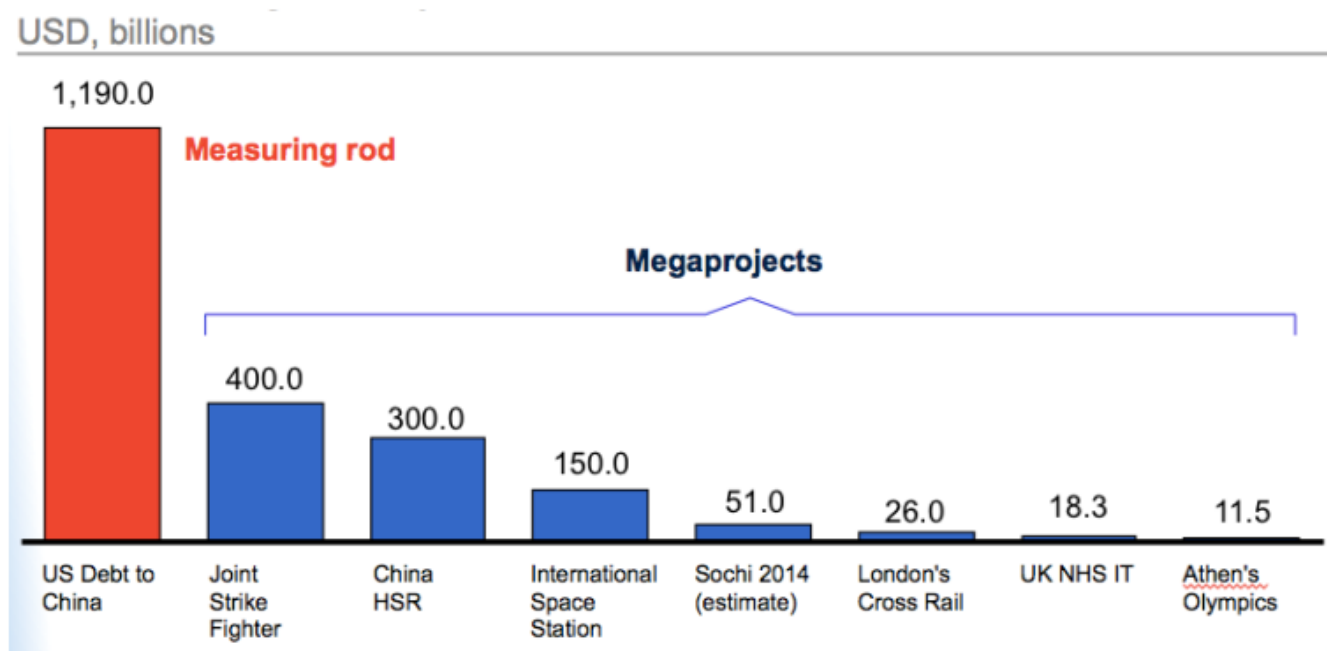


Figure 3: Size of selected megaprojects, measured against one of the largest dollar-figures in the world, accumulated US debt to China.¹

However, Megaprojects are not only large, it is growing constantly ever larger in a long historical figures with no ceiling. As the Skyscraper index is showing.

Figure 4 Skyscraper Index. (Gardner, 2015)

¹ (Flyvbjerg, 2014, p. 27)

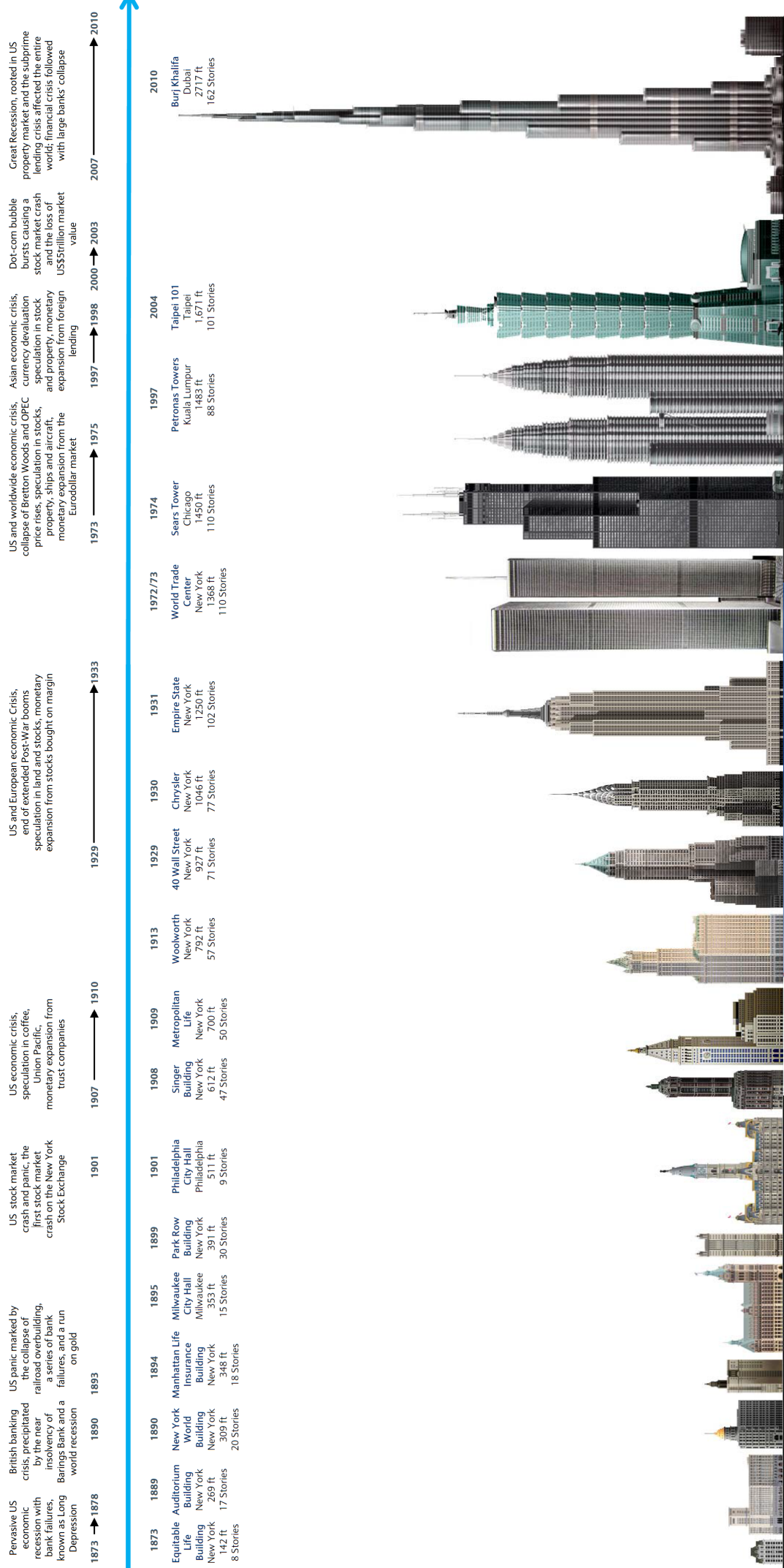


Figure 4 Skyscraper Index. (Gardner, 2015)

When New York's Chrysler Building opened in 1930 at 319 meters it was the tallest building in the world. The record had been since exceeded seven times and since 1998 the tallest building has significantly been located in emerging economies with Dubai's Burj Khalifa presently holding the record at 828 meters. That is a 160% increase in building height over 80 years.

Similarly, the longest bridge span has grown even faster, by 260 percent over approximately the same period. Measured by value, the size of infrastructure projects has grown by 1.5 to 2.5 percent annually in real terms over the past century, which is equivalent to a doubling in project size two to three times per century. Overcoming with the increased scale which requires a constant and pressing issue in megaproject management. (Flyvbjerg, 2014, p. 6).

"Mega" comes from the Greek word "Megas" and means great, large, vast, big, high, tall, mighty, and important. As a scientific and technical unit of measurement "mega" specifically means a million. If we were to use this unit of measurement in economic terms, then strictly speaking megaprojects would be million-dollar (or euro, pound, etc.) projects, and for more than a hundred years the largest projects in the world were indeed measured mostly in the millions. This changed with the Second World War, Cold War, and Space Race. Project costs now escalated to the billions, led by:

- Manhattan Project (1939-46), a research and development program that produced the first atomic bomb.
- Apollo program (1961-72), which landed the first humans on the moon (Morris, 1994) (Flyvbjerg, 2014, p. 7).

The first known use of the term "megaproject" was in 1976, but before that, from 1968, "mega" was used in "megacity" and later, from 1982, as a standalone adjective to indicate "very large." (Merriam-webster, 2018).

So The word "Mega" means million (1,000,000) and the word "Giga" means billion (1,000,000,000), but still the term "Giga-project" is not used even to describe the projects which are between 50-100 billion us dollars such as the California and UK high-speed rail projects, or which exceed 100 billion us dollars such as the International Space Station and the Joint Strike Fighter.

If there are projects of this size would be ranked among the world's top 100 countries measured by gross domestic product, larger than the economies of a small developing country. When projects of this size go wrong, whole companies and national economies suffer. As shown before in the previous figure the relation between the world financial crisis and the large-scale project is very critical.

2.1.2 The Megaprojects Business?

Nevertheless, megaprojects are not only large and growing constantly larger, they are being built in ever-greater numbers at ever-greater value. The McKinsey Global Institute (2013) estimates global infrastructure spending at USD 3.4 trillion per year (2013-2030), or approximately four percent of the total global gross domestic product, mainly delivered as large-scale projects (McKinsey Global Institute, 2013). The Economist (June 7, 2008:80) similarly estimated infrastructure spending in emerging economies at USD 2.2 trillion annually for the period 2009-2018. To illustrate the accelerated pace at which spending is taking place, consider that in the five years from 2004 to 2008, China spent more on infrastructure in real terms than in the whole of the 20th Century. That is an increase in the spending rate of factor twenty. Similarly, from 2005 to 2008, China built as many kilometers of high-speed rail as Europe did in two decades, and Europe was extraordinarily busy building this type of infrastructure during this period. (Flyvbjerg, 2014).

Not at any time in the history of humankind has infrastructure spending been this high measured as a share of world GDP, according to The Economist, who calls it "the biggest investment boom in history." Moreover, that's just infrastructure. If we include the many other fields where megaprojects are the main delivery model – oil and gas, mining, aerospace, defense, ICT, supply chains, mega-events, etc. – then a conservative estimate for the global megaproject market is USD 6-9 trillion per year or approximately eight percent of total global gross domestic product. For perspective, consider this is equivalent to spending five to eight times the accumulated US debt to China, every year. That is a big business by any definition of the term. (Flyvbjerg, 2014).

Moreover, megaprojects have proved remarkably recession-proof. In fact, the downturn from 2008 helped the megaprojects business grow further by showering stimulus spending on everything from transportation infrastructure to ICT. From being a fringe activity – albeit a spectacular one – mainly reserved for rich, developed nations, megaprojects have recently transformed into a global multi-trillion-dollar business that affects all aspects of our lives, from our electricity bill to how we shop and what we do on the Internet to how we commute. With so many resources tied up in ever-larger and ever-more megaprojects, at no time has the management of such projects been more important. The potential benefits of building the right projects in the right manner are enormous and are only matched by the potential waste from building the wrong projects, or building projects wrongly. Never has it been more important to choose the most fitting projects and get their economic, social, and environmental impacts right (Flyvbjerg, et al., 2003). Never has systematic and valid knowledge about megaprojects therefore been more important to inform policy, practice, and public debate in this highly costly area of business and government. (Flyvbjerg, 2014, p. 6).

2.1.3 The Four Sublimes

What drives the megaproject boom? Why are mega-projects so attractive to decision makers? The answer may be found in the so-called "four sublimes" of megaproject management. The first of these, the "technological sublime," is a term variously attributed to Miller (1965) and Marx (1967) to describe the positive historical reception of technology in American culture during the nineteenth and early twentieth centuries. (Frick, et al., 2008, p. 239) introduced the term to the study of megaprojects and here describes the technological sublime as the rapture engineers and technologists get from building large and innovative projects with their rich opportunities for pushing the boundaries for what technology can do, like building the tallest building, the longest bridge, the fastest aircraft, the largest wind turbine, or the first of anything. Frick applied the concept in a case study of the multi-billion-dollar New San Francisco-Oakland Bay Bridge, concluding "*the technological sublime dramatically influenced bridge design, project outcomes, public debate, and the lack of accountability for its [the bridge's] excessive cost overruns*". (Frick, et al., 2008, p. 262).

(Flyvbjerg, et al., 2012) Proposed three additional sublims, beginning with the "political sublime," which here is understood as the rapture politicians get from building monuments to themselves and their causes. Mega-projects are manifest, garner attention, and lend an air of pro-activeness to their promoters. Moreover, they are media magnets, which appeals to politicians who seem to enjoy few things better than the visibility they get from starting megaprojects. Except maybe cutting the ribbon of one in the company of royals or presidents, who are likely to be present lured by the unique monumental and historical import of many megaprojects. This is the type of public exposure that helps get politicians reelected. They therefore actively seek it out.

Next, there is the "economic sublime," which is the delight business people and trade unions get from making lots of money and jobs off megaprojects. Given the enormous budgets for megaprojects there are ample funds to go around for all, including contractors, engineers, architects, consultants, construction and transportation workers, bankers, investors, landowners, lawyers, and developers. Finally, the "aesthetic sublime" is the pleasure designers and people who appreciate good design get from building, using, and looking at something very large that is beautiful, like San Francisco's Golden Gate Bridge or Sydney's Opera House.

All four sublims are important drivers of the scale and frequency of megaprojects described above. Taken together they ensure that strong coalitions exist of stakeholders who benefit from megaprojects and who will therefore work for more such projects.

Type of Sublime	Characteristic
Political	The rapture politicians are using Mega-projects to promote themselves and their causes, and from the visibility this generates with the public and media.
Technological	The excitement architects and engineers working hard to achieve what is possible in "longest-tallest-fastest" type of projects.
Economic	The delight business people and the whole economy is looking for making lots of money and jobs out of megaprojects, including for contractors, workers in construction and transportation, consultants, bankers, investors, landowners, lawyers, and developers.
Aesthetic	The pleasure designers and people who love good design would like to see a landmark and be using something very large that is also iconic and beautiful, like the Golden Gate bridge.

Table 1: The "Four Sublims" that drive megaproject development.

For policymakers, investment in infrastructure megaprojects seems particularly coveted, because, if done right, such investment:

- Creates and sustains employment.
- Contains a large element of domestic inputs relative to imports.
- Improves productivity and competitiveness by lowering producer costs.
- Benefits consumers through higher-quality services.
- Improves the environment when infrastructures that are environmentally sound replace infrastructures that are not. (Helm, 2008).

Nevertheless, there is a big "if" here, as in "if done right." Only if this is disregarded – as it often is by promoters and decision makers for megaprojects – can megaprojects be seen as an effective way to deliver infrastructure. In fact, conventional megaproject delivery – infrastructure and other – is highly problematic with a dismal performance record in terms of actual costs and benefits, as we will see below. The following characteristics of megaprojects are typically overlooked or glossed over when the four sublimines are at play and the megaproject format is chosen for delivery of large-scale ventures:

1. Megaprojects are inherently unstable due to lengthy planning horizons and complex interfaces. (Flyvbjerg, 2006, pp. 5-15)
2. A team of Managers and Engineers without deep domain experience, who changes throughout the long project cycles that apply to megaprojects, causing a weak leadership, drives often projects.
3. Decision-making, planning, and management are processes that involve multiple stakeholders with conflicting interests "Public & Private" (Aaltonen & Kujala, 2010, pp. 381-397)
4. Technology and designs standards are changing frequently, leading to "uniqueness bias" among the project team, who tend to see their projects as singular, which prevents learning from other projects.² (Flyvbjerg & Budzier, 2013, p. 28).

² "Uniqueness bias" is here defined as the tendency of planners and managers to see their projects as singular. This particular bias stems from the fact that new projects often use non-standard technologies and designs, leading managers to think their project is more different from other projects than it actually is. Uniqueness bias impedes managers' learning, because they think they have nothing to learn from other projects as their own project is unique. This lack of learning may explain why managers who see

5. Frequently happened that the project team agrees about a certain path without looking at other alternatives, and leading to increasing the commitment with time. "Fail fast" does not apply; "fail slow" does (Cantarelli, et al., 2010, pp. 792-807) (Ross & Staw, 1993, pp. 701-732) (Drummond, 1998, pp. 919-929).
6. Due to the huge amount of money involved, principal-agent problems and rent-seeking behavior³ are common. (Eisenhardt, 1989, pp. 57-74) (Stiglitz, 1989) (Flyvbjerg, 2009, pp. 170-193).
7. The project scope or ambition level will usually change considerably over the time.
8. Delivery is high-risk, extreme events with massively negative outcomes are more likely to happen (Taleb, 2010). Project team tends to ignore this, treating projects as if they totally under control.
9. Statistical proves that such complexity and unplanned occasions are regularly unaccounted for, leaving budget and time contingencies insufficient. (Flyvbjerg, 2014, p. 8)
10. Misinformation about costs, schedules, benefits, and risks is common throughout project development and decision-making. The result is cost overruns, delays, and benefit shortfalls that reduce the project survival abilities during the project life cycle. (Flyvbjerg, 2014, p. 8).

2.1.4 Cost overrun in Megaprojects

Simply, cost overrun is when the costs of a project are greater than the estimated budget for that project. The term can be applied to the budget of a government, organization, department, team, project, function or task. The following are the primary types of cost overrun:

- Estimates

their projects as unique perform significantly worse than other managers. Project managers who think their project is unique are therefore a liability for their project and organization. For megaprojects this would be a mega-liability. (Flyvbjerg & Budzier, 2013). (Flyvbjerg, 2014, p. 30).

³ Rent-seeking is an individual's or entity's use of company, organizational or individual resources to obtain economic gain without reciprocating any benefits to society through wealth creation. Read more: Rent-Seeking <https://www.investopedia.com/terms/r/rentseeking.asp#ixzz5lhMog5H9>

Cost estimation is too low because of unrealistic optimization or a poor understanding of the details of the required tasks. Techniques such as reference class forecasting and benchmarking may be used to improve the accuracy of estimates. Due to the complexity of designs and details, the best of estimates can become inaccurate. It is a common aspect in project management to include cost contingency in a budget.

- Cost escalation

Cost escalation is an increase in the price of a specific material that occurs over time. For example, the price of steel can unpredictable rise and fall over a short period of time, in the case some contractors buy the whole amount of steel for the project at once, or some contracts have a clause to modify the item price in case the price change higher than a certain percent.

- Scope creep

To describe scope creep imagine a project with more work and efforts than what was planned in terms of its budget and schedule. This can happen when business units think of features as the project develops. Alternatively, it can happen when individuals or teams get creative and start adding undocumented details. Project management processes and controls are typically designed to prevent scope creep by Synchronization budget and schedule with each change to scope.

- Risk

Risks are potential conditions and events that may cause losses. Such as, unusually bad weather can cause delays to a construction project. Risk can also include factors such as the performance of participants of the project. Risk management, the process of identifying, analyzing, evaluating, tracking risk which helps to prevent cost overrun. The potential costs of risks can also be considered in cost contingency. (Spacey, 2017)⁴

Historical data for megaprojects have a long story with cost overruns. Nine out of ten Mega-projects have cost overruns. Which can be divided into two categories: common cost overruns (up to 50%) and uncommon costs overruns (more than 50%). As examples of Cost overrun:

⁴ <https://simplicable.com/new/cost-overrun>

- The Channel tunnel “English tunnel” “Euro-Tunnel” project, the longest underwater rail tunnel in Europe, connecting the UK and France, was 80% in real terms.
- Denver International Airport, 200%. Boston's Big Dig, 220 percent.
- The UK National Health Service IT system, 400-700%.
- The Sydney Opera House, 1,400% (Table 4).

Overrun is a problem in both private and public sector projects, and things are not improving; overruns have stayed high and constant for the 70-year period for which comparable data exist. The location of the project in the world did not change the fact that projects suffer from cost overruns even if data are available but the problem still exists. Similarly, benefit shortfalls of up to 50% are also common, and above 50% still not uncommon, and the problem still with no signs of improvements over time and geography (Flyvbjerg, et al., 2002, p. 279) (Flyvbjerg, et al., 2005, pp. 131-146).

Project	Cost Overrun (%)
Suez Canal, Egypt	1,900
Scottish Parliament Building, Scotland	1,600
Sydney Opera House, Australia	1,400
Montreal Summer Olympics, Canada	1,300
Concorde supersonic aeroplane, UK, France	1,100
Troy and Greenfield railroad, USA	900
Excalibur Smart Projectile, USA, Sweden	650
Canadian Firearms Registry, Canada	590
Lake Placid Winter Olympics, USA	560
Medicare transaction system, USA	560
National Health Service IT system, UK	550
Bank of Norway headquarters, Norway	440
Furka base tunnel, Switzerland	300
Verrazano Narrow bridge, USA	280
Boston's Big Dig artery/tunnel project, USA	220
Denver international airport, USA	200
Panama canal, Panama	200
Minneapolis Hiawatha light rail line, USA	190
Humber bridge, UK	180
Dublin Port tunnel, Ireland	160
Montreal metro Laval extension, Canada	160
Copenhagen metro, Denmark	150
Boston-New York-Washington railway, USA	130
Great Belt rail tunnel, Denmark	120
London Limehouse road tunnel, UK	110
Brooklyn bridge, USA	100
Shinkansen Joetsu high-speed rail line, Japan	100
Channel tunnel, UK, France	80
Karlsruhe-Bretten light rail, Germany	80
London Jubilee Line extension, UK	80
Bangkok metro, Thailand	70
Mexico City metroline, Mexico	60
High-speed Rail Line South, The Netherlands	60
Great Belt east bridge, Denmark	50

Table 2 Large-scale projects have a calamitous history of cost overrun.

Combine the large cost overruns and benefit shortfalls with the fact that business cases, cost-benefit analyses, and social and environmental impact assessments are typically at the core of planning and decision-making for megaprojects and we see that such analyses can generally not be trusted. For example:

- Rail projects an average cost overrun of 44.7% combines with an average demand shortfall of 51.4%.
- Roads, an average cost overrun of 20.4% combines with a fifty–fifty risk that demand is also wrong by more than 20%.

With errors and prejudices of this size in the forecasts that form prejudices for business cases, cost–benefit analyses, and social and environmental impact assessments, this data is not with a high degree of certainty, be strongly misleading. "*Garbage in, garbage out*" (Flyvbjerg, 2009, p. 344–367).

As an example, the Channel tunnel in more focus. The project was originally promoted as highly beneficial both economically and financially. At the initial public offering, Eurotunnel, the private owner of the tunnel, tempted investors by telling them that 10% "would be a reasonable allowance for the possible impact of unforeseen circumstances on construction costs."⁵ In fact, costs went 80% over budget for construction, as mentioned above, and 140% for financing (Flyvbjerg, 2014, p. 11).

The earnings have been half of those expected. As a result, the project has proved non-workable, with an internal rate of return on the investment that is negative, at minus 14.5% with a total loss to the British economy of 17.8 billion US dollars. Thus, the Channel tunnel take away from the economy instead of adding to it. This is difficult to believe when you use the service, which is fast, convenient, and competitive with alternative modes of travel. However, each passenger is heavily supported. Not by the government this time, but by the many private investors who lost their money when Eurotunnel went bankrupt and was financially restructured. This drives home an important point: A megaproject may well be a technological success, but a financial failure and many are. An economic and financial ex post evaluation of the Channel tunnel, which systematically compared actual with forecasted costs and benefits, concluded that "*the British Economy would have been better off had the Tunnel never been constructed*" (Anguera, 2006, p. 291–315).

Other examples of non-feasible megaprojects:

- Sydney's Lane Cove tunnel.
- The high-speed rail connections at Stockholm and Oslo airports.
- The Copenhagen metro.
- Denmark's Great Belt tunnel.

Delays are a separate problem for megaprojects and delays cause both cost overruns and benefit shortages. For example, preliminary results from a study undertaken at

⁵ Quoted from "Under Water Over Budget," *The Economist*, 7 October 1989, 37–8.

Oxford University, based on the largest database of its kind, suggest that delays on dams are 45% on average. Thus if a dam was planned to take 10 years to construct, from the decision to build until the dam became operational, then it actually took 14.5 years on average. Modeled the relationship between cost overrun and length of implementation phase based on a large data set for major construction projects. They found that on average a one-year delay or other extensions of the implementation phase related to an increase in percentage cost overrun of 4.64%. (Flyvbjerg, 2004, pp. 3-18).

For more explanation about the critical situation of delivering a mega-project to the national and world economy, for example, a project the size of London's 26 billion dollars Cross-rail project, a one-year delay would cost 1.2 billion dollars extra, or 3.3 million dollars per day. *"The key lesson here is that in order to keep costs down, implementation phases should be kept short and delays small"* (Flyvbjerg, 2014, p. 10). Here comes the need for tools to assist a beneficial feasibility study, offering the ability to check many scenarios and designs for the project, also flexible to accommodate the possible changes during execution. This should not be seen as an excuse for fast-tracking projects, i.e., rushing them through decision making for early construction start. Front-end planning needs to be thorough before deciding whether to give the green light to a project or stopping it (Williams, 2010). Nevertheless, often the situation is the exact opposite. Front-end planning is weak, bad projects are not stopped, implementation phases and delays are long, costs soar, and benefits and income realization falls back into the future. For debt-financed projects, this is a recipe for disaster, because project debt grows while there is no income stream to service interest payments, which are then added to the debt, etc. As a result, many projects end up in the so-called "debt trap" where a combination of escalating construction costs, delays, and increasing interest payments makes it impossible for income from a project to cover costs, rendering the project non-feasible. That is what happened to the Channel tunnel and Sydney's Lane Cove tunnel, and other projects.

Not all the previous explanations say that projects that on budget and time with the expected benefits do not exist. The Guggenheim Museum Bilbao is an example of that rare generation of projects. Similarly, recent metro extensions in Madrid were built on time and to budget as were a number of industrial projects (Flyvbjerg, et al., 2005, pp.

50-59). To illustrate, as part of ongoing research on success in megaproject management the present author and his associates are trying to establish a sample of successful projects large enough to allow statistically valid answers. However, so far they have failed. Why? Because success is so rare in megaproject management that at present it can be studied only as small-sample research, whereas failure may be studied with large samples of projects. (Flyvbjerg, 2014, p. 11).

Success in megaproject management is typically defined as projects being delivered on budget, time, and benefits. If, as the evidence indicates, approximately:

- one out of ten megaprojects is on budget
- one out of ten is on schedule
- one out of ten is on benefits

Then approximately one in a thousand projects is a success, which means 100's of possible disasters.

Even if the numbers were wrong by a factor two – so that two, instead of one, out of ten projects were on target for cost, schedule, and benefits, respectively – the success rate would still be dismal, now eight in a thousand. This serves to illustrate what may be called the "iron law of megaprojects": Over budget, over time, repeatedly again (Flyvbjerg, Bent, 2011, pp. 321-344)⁶. Best practice is an outlier, average practice a disaster in this interesting and very costly area of management.

- **The Relation between mega projects (Skyscrapers as an example) and financial crisis**

Even in the ancient era, Mega-projects exists. In this research I would like to refer to the great pyramid of Giza as the first and still exist Mega-project in the human history, *Pharaoh Khufu* began the first Giza pyramid project, circa 2550 B.C. His Great Pyramid is the largest in Giza and with a height of 481 feet (147 meters) above the plateau. Its estimated 2.3 million stone blocks each weigh an average of 2.5 to 15 tons. (HANDWERK, 2018)

⁶ The Economist (March 10, 2012: 55) describes the near-certainty of large cost overruns and delays in transportation infrastructure projects as "the iron law of infrastructure projects." Our data show the iron law is not limited to infrastructure; it applies to megaprojects in general and covers benefit shortfalls in addition to cost overruns and delays.

The ancient engineering feats at Giza were so impressive that even today scientists cannot be sure how the pyramids were built. Yet they have learned much about the people who built them and the political power necessary to make it happen. Archaeological digs on the fascinating site have revealed a highly organized community, rich with resources that must have been backed by strong central authority.

It is likely that communities across Egypt contributed workers, as well as food and other essentials, for what became in some ways a national project to display the wealth and control of the ancient pharaohs. In addition, there is a question, but technically, without an answer “*Did Egypt suffer from a financial crisis after the project was built?*”

Then, it comes to the current and last centuries to find out the relation between mega projects (Skyscrapers as an example) and financial crisis, in this figure, it will be noticed.

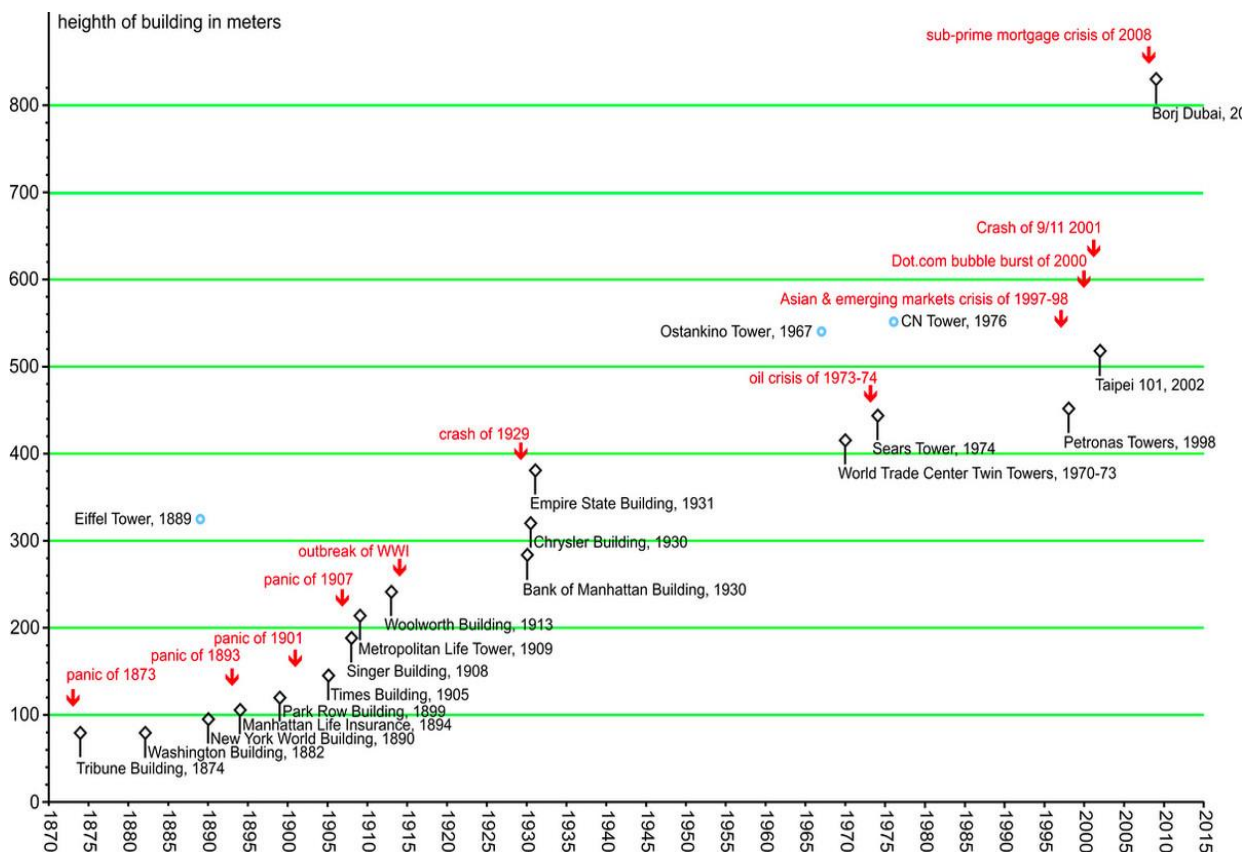


Figure 5 the construction of the world's tallest building plotted against major stock market crashes.⁷

⁷ <https://ericrossacademic.wordpress.com/2013/02/12/presenting-the-skyscraper-index-of-stock-market-crashes/>

Note: monumentally tall structures such as the Eiffel and CN towers are included in the graph for reference sake but are not part of the data analysis or theorization as they are not rent-producing developments reflecting conditions in the real-estate market. (Ross, 2013, pp. 701-732).

That was about the projects that already built, but some Mega-project are still under construction, what will happen? The hiding hand according to Hirschman will keep the project on the track to be accomplished whatever it takes or some strong events and situations can lead to other decisions, for example in Riyadh's Bureau of Capital and Operational Spending Rationalization is now assessing the projects that are under 25 percent complete. Sources familiar with the cost-cutting measures say some projects could be retendered so they can be executed in partnership with the private sector, possibly through build-operate-transfer (BOT) contracts while other projects could be suspended. (Alwaght News, 2017)

Saudi Arabia cut infrastructure projects last year, as well. In February, Finance Minister Mohammed Al-Jadaan said, *"this saved the monarchy 80 billion riyals (\$21.33 billion)"*. In a January report, consultants Faithful + Gould said Saudi Arabia may scrap at least \$13.3 billion in projects. Officials are likely to give higher priority to social projects and businesses like water and power generation, while vanity projects like sports stadiums, some transport systems, and nuclear projects are likely to be canceled. (Alwaght News, 2017)

2.1.5 Feasible or Not? Hirschman's Hiding Hand, Revisited

One may argue, of course, as famously done by Hirschman (Hirschman, 1967a), that if people knew in advance the real costs and challenges involved in delivering a large project, "they probably would never have touched it" and nothing would ever get built. Therefore, it is better not to know, because ignorance helps get projects started, according to this argument. The following is a recent and particularly candid articulation of the *"nothing-would-ever-get-built"* argument, by former California State Assembly speaker and mayor of San Francisco, Willie Brown, discussing a large cost overrun on the San Francisco Transbay Terminal megaproject in his San Francisco Chronicle column (July 28, 2013, emphasis added):

"News that the Transbay Terminal is something like \$300 million over budget should not come as a shock to anyone. We always knew the initial estimate was way under the real cost. Just like we never had a real cost for the [San Francisco] Central Subway or the [San Francisco-Oakland] Bay Bridge or any other massive construction project. *"In the world of civic projects, the first budget is really just a down payment. If people knew the real cost from the start, nothing would ever be approved. The idea is to get going. Start digging a hole and make it so big, there's no alternative to coming up with the money to fill it in."*

"Hiding the total budget of the project is a political decision, though a well-prepared feasibility study is an initial tool to assist the decision maker, however in case this information was not announced to the public, this is another story." (Flyvbjerg, 2014, p. 12).

People are "tricked" into making Mega-projects by their own ignorance. Maybe this is positive because just as people underestimate the difficulties in doing large-scale projects they also underestimate their own creativity in dealing with the problems, but this is a very critical concept especially when it comes to Projects that may cause national or global economic crisis. *"the only way in which we can bring our creative sources fully into play is by misjudging the nature of the task, by presenting it to ourselves as more routine, simple, undemanding of genuine creativity than it will turn out to be."* Hirschman called this the "**principle of the Hiding Hand**" and it consists of "some sort of invisible or hidden hand that beneficially hides difficulties for us," where the error of underestimating difficulties is offset by a "roughly similar" error in underestimating our ability to overcome the difficulties thus helping *"accelerate the rate at which 'mankind' engages successfully in problem-solving."* (Hirschman, 1967a).

In a study of early industrial infrastructure projects "in praise of folly" – similarly identified what is called "creative error" in project development as, first, "miscalculation or sheer ignorance" of the true costs and benefits of projects and, second, such miscalculation being "crucial to getting an enterprise launched at all." Sawyer argued that such "creative error" was key to building a number of large and historically important projects like the Welland Canal between Lake Erie and Lake Ontario, the Panama Canal, the Middlesex Canal, the Troy and Greenfield Railroad, and early Ohio roads. For these and other projects, Sawyer found that "**the error in estimating costs was**

at least offset by a corresponding error in the estimation of demand" (Sawyer, 1951, p. 200).

It is easy to understand the reason that Hirschman's and Sawyer's theories have become popular, especially with people who benefit from megaprojects. The theories encourage promoters and decision makers, like Willie Brown to just go ahead with projects and not worry too much about the costs or other problems, because the Hiding Hand will take care of them, eventually. Moreover, in any case, who wants to be the killjoy stopping large projects from going ahead with an overdose of truth? (Hirschman, 1967b, pp. 10-23) Was an immediate hit with practitioners, from Washington's policy establishment to the United Nations to the World Bank? The head of the bank's Economics Department told Hirschman, "*You've helped in part to remove the unease that I have had in reflecting on the fact that if our modern project techniques had been used, much of the existing development in the world would never have been undertaken*" (Adelman, 2013).

To follow the stream of the Hiding Hand logic, there were many question marks around the huge cost overrun of the Sydney Opera House, "*Did people really think that the Sydney Opera House would come in on the budget? Or did we all agree to accept the deception and engage in wishful thinking in order to make something that we really wanted happen? ... Do Australians really regret those dramatic sails in the harbor? Or would they have regretted more the decision [not to build] that would most reasonably have been based on a fair prediction of costs?*" (Teitz & Michael, 2010, p. 429–442).

Australians do not regret the Sydney Opera House, given what it has done for Australia – though at first the building was not called "*dramatic sails in the harbor*," but "*copulating white turtles*" and "something that is crawling out of the ocean with nothing good in mind" designed by an architect with "*lousy taste*" (Reichold, et al., 2004). Non-Australians may feel regret, however, for example, the architect of the Opera House, what is his name? Does anybody know? Which is surprising as it is the architect of nearly the most iconic building of the 20th century. Moreover, if anybody knows the architect is the Dane Jørn Utzon, why can they hardly ever mention another building designed by him? Because the overrun on the Opera House and the following controversy destroyed Utzon's career and kept him from building more masterpieces. He became that most tragic figure in architecture, the one building architect. This is the real regret –

and real cost – of the Sydney Opera House. Not premier Joe Cahill's deliberate deception about the cost – to get approval in Parliament – and the consequential huge cost overrun (Flyvbjerg, et al., 2005, pp. 131-146).

Today, much more and better data and theories on megaproject performance are available than at the time of Hirschman and Sawyer “1960's”. While there may be elements of truth in these authors' theories types of projects and contexts, their samples and conclusions are not representative of the project population. In particular, their odd asymmetrical assumption that optimism would apply to cost estimates but pessimism to estimates of benefits has been solidly disproved (Kahneman & Tversky, 1979, pp. 313-327) and behavioral economists building on their work. They found that optimism bias applies to estimates of costs and benefits, both. *“An optimistic cost estimate is low and leads to **cost overrun**, whereas an optimistic benefit estimate is high and results in **benefit shortfalls**. Thus errors of estimation do not cancel each other out, as Hirschman would have it; the exact opposite happens, errors generally reinforce each other”* (Flyvbjerg, 2014, p. 16).

Megaproject planners and managers would, therefore, be ill-advised to count on Hiding Hands, creative errors, or any other general principle according to which underestimates of costs would be balanced by similar underestimates of benefits. We also now know it would be equally foolhardy to assume that downstream human creativity may be generally counted on to solve problems that planners and managers overlook or underestimate when the decision is made to go ahead with a project. The data show that for too many projects with front-end problems such creativity never materializes and projects end up seriously impaired or non-viable. Initial problems, if not dealt with up front, tend not to go away. The iron law of megaprojects, described above, trumps Hirschman's Hiding Hand at a high level of statistical significance, and we know why. The Hiding Hand is itself an example of optimism and does therefore not capture the reality of megaproject management. For such capture and true explanatory power, we must turn to theories of optimism bias, the planning fallacy, strategic misrepresentation, and principal-agent behavior.

2.1.6 Corruption in Megaprojects

- **Why in Mega-projects?**

- **Uniqueness:** No two-construction projects are the same making comparisons difficult and providing opportunities to inflate costs and conceal bribes.
- **Complex transaction chains:** The delivery of projects involves many professional disciplines and tradespeople and numerous contractual relationships that make control measures difficult to implement. “especially for this problem a solid key solution will be presented in the future recommendations”
- **Work is concealed:** Materials and workmanship are often hidden, e.g. steel reinforcing is cast in concrete, masonry is covered with plaster and cables and pipes enclosed in service ducts.
- **Official bureaucracy:** Numerous approvals are required from the government in the form of licenses and permits at various stages of the delivery cycle, each one providing an opportunity for bribery.
- **The scale of investments:** Investments in economic infrastructure such as dams, airports, and railways can cost tens of billions of dollars making it easier to conceal bribes and inflate claims (Transparency International , 2018).

- **The need for action**

- Corruption is damaging:
 - It damages the developed as well as developing countries, by constructing projects, which are unnecessary, unfeasible, dangerous, and overestimated. This can cause losses of lives, poverty, economic damage, and underdevelopment.
 - It damages companies, causing tendering uncertainty, wasting tender expenses, increasing project costs, economic damage, and reducing project opportunities.

- It damages individuals, reducing morale, causing criminal prosecution, fines and imprisonment.
- Project Anti-Corruption Monitoring

Corrupt practices are normally concealed. It is very difficult for anyone who do not have the appropriate skills, who does not have access to the relevant documents and people, and who does not have an in-depth involvement in the project, to be able to prevent or uncover these practices. Independent monitoring mechanisms need to be introduced at project level which is capable of preventing and identifying corrupt practices. It recommends the development and implementation of mechanisms under which:

- a. The participants in projects commit to act with absolute integrity in relation to the project.
- b. An independent expert who is given appropriate access to documents and individuals for the duration of the project monitors compliance with the integrity commitments throughout major projects.
- c. Breach of the commitments leads to contractual and, if appropriate, a criminal sanction.

It is obvious the critical need to a tool and technology to allow the quick access relevant documents and project details to uncover the suspected practices and at the same time prove it with all the necessary historical data. (UK Anti-Corruption Forum, 2006).⁸

2.1.7 The main stream still going in the same direction

In sum, one does megaprojects – and megaproject management – a disservice if one claims they can only be done through the **Hiding Hand**, creative error, or downright deception. It is, undoubtedly, quite common for project promoters and their planners and managers to believe their projects will benefit society and that, therefore, they are justified in “*cooking*” costs and benefits to get projects built (Wachs, 1990, pp. 141-157) (Pickrell, 1992, pp. 158-176). Such reasoning is faulty, however. Underestimating costs and overestimating benefits for a given project – which is the common pattern,

⁸ UK Anti-Corruption Forum, www.transparency.org

as described above – leads to a falsely high benefit-cost ratio for that project, which in turn leads to two problems:

- The project may be started despite the fact it is not financially and economically viable.
- This project may be started instead of another project that would have shown itself to yield higher returns than the project started, had the real costs and benefits of both projects been known.

Both cases lead to inefficiency, that is, the misallocation of resources and, for public projects, waste of public and private wealth. Thus for reasons of economic efficiency alone the argument must be rejected “*cost underestimation and benefit overestimation are justified to get projects started*” (Flyvbjerg, 2014, p. 17).

A first answer to the skeptics’ question of whether enough megaprojects would be undertaken if some form of misrepresentation of costs and benefits was not involved is, therefore, that even if misrepresentation was necessary in order to get projects started, such misrepresentation would typically not be defensible in liberal democracies – and especially not if it was deliberate – for economic, legal, and ethical reasons. (Flyvbjerg, 2014, p. 18).

A second answer is that misrepresentation is not necessary to undertake projects, because many projects exist with sufficiently high benefits and low enough costs to justify building them. Even in the field of innovative and complex architecture, which is often singled out as particularly difficult, there is the Basque Abandoibarra urban regeneration project, including the Guggenheim Museum Bilbao, which is as complex, innovative, and iconic as any signature architecture, and was built on time and budget. Complex rail projects, too, like the Paris-Lyon high-speed rail line and the London Docklands light railway extension have been built to the budget. The problem is not that projects worth undertaking do not exist or cannot be built on time and on budget. The problem is that the dubious and widespread practices of underestimating costs and overestimating benefits used by many megaproject promoters, planners, and managers to promote their pet project create a distorted hall-of-mirrors in which it is extremely difficult to decide which projects deserve undertaking and which not. (Flyvbjerg, 2014, p. 18).

In fact, the situation is even worse than that. The common practice of depending on the Hiding Hand or creative error in estimating costs and benefits – thus "showing the project at its best" as an interviewee put it in a previous study – results in an inverted Darwinism, i.e., the "*survival of the unfittest*" (Flyvbjerg, 2009). It is not the best projects that get implemented in this manner, "*the projects that look best on paper. And the projects that look best on paper are the projects with the largest cost underestimates and benefit overestimates*", (Flyvbjerg, 2014, p. 19). Other things being equal. "*The larger the cost underestimate on paper, the greater the cost overrun in practice and the larger the overestimate of benefits, the greater the benefit shortfall*" (Flyvbjerg, 2014, p. 20). Therefore the projects that have been made to look best on paper become the worst projects in reality, in the sense that they are the very projects that will encounter most problems during construction and operations in terms of the largest cost overruns, benefit shortfalls, and risks of non-viability. They have been designed like that, as disasters waiting to happen. (Flyvbjerg, 2014, p. 19).

The result is, as even the industry's own organ, the Major Projects Association, has said, that "*too many projects proceed that should not have done*" (Morris & Hough, 1987). "*One might add that projects also exist that do not proceed but should have, had they not lost out, not to better projects but to projects with "better" creative error, that is "better" manipulated estimates of costs and benefits*" (Flyvbjerg, 2014, p. 20).

2.2 Introduction to Building Information Modeling "BIM"

2.2.1 Definition for BIM

There is no globally accepted definition of BIM, but most previous researches provide approximately similar response to the question "what is BIM?" The reason there is no agreed definition and the definition is changing with the progress of information technology within the AEC industry. Herby a review for most of the common definitions:

"Building Information Modeling (BIM) is one of the most promising developments in the architecture, engineering, and construction (AEC) industries. With BIM technology, one or more accurate Virtual models of a building are constructed digitally. They support design through its phases, allowing better analysis and control than manual processes.

When completed, these computer-generated models contain precise geometry and data needed to support the construction, fabrication, and procurement activities through which the building is realized.” (Eastman, et al., 2011, p. 1)

“BIM Building Information Modeling as a process—as opposed to software, technology, or tool of generating and managing building data during its complete lifecycle, from conceptual design through maintenance and operation of the building.” (Deutsch, 2011, p. xviii)

“It is important to understand that though most have come to understand BIM as a 3D tool, it is also an information-rich database that links to and controls those model components; this is often referred to as “parametric modeling.” There is significant value in the three-dimensional aspect of BIM, but its ultimate value lies in the ability to aggregate, edit, sort, and compile this information to drive at better answers to design and construction questions such as “What is the best sequence to install this piece of equipment?”, “How much square feet of raised flooring do we have in this facility?”, and “What are the parts I need to build this manufacturing plant addition?” If a 3D element is in the model, chances are a whole host of information is behind it that can be used in a variety of ways.” (Brad & Dave, 2015, p. 15)

2.2.2 The current AEC business model

Currently, the Projects delivery process remains fragmented, and generally, it is documented on paper for communication. Errors and omissions in paper documents often cause unpredictable field costs, delays, and periodical lawsuits between the different parties in a project team. These problems increase financial expense and delays. Efforts to highlight such problems have included:

Alternative organizational structures such as the design-build method; the use of real-time technology, such as project Web sites for sharing plans and documents; and the implementation of 3D CAD tools. Though these methods have improved the timely exchange of information, they have done little to reduce the severity and frequency of conflicts caused by paper documents or their electronic equivalents.

One of the most common problems associated with 2D-based communication during the design phase is the considerable time and expense required to generate critical assessment information about a proposed design, including cost estimates, energy-

use analysis, structural details, and so forth. These analyses are normally done last when it is already too late to make important changes. Because these iterative improvements do not happen during the design phase, value engineering must then be undertaken to address inconsistencies, which often results in compromises to the original design. (Eastman, et al., 2011, p. 2)

Regardless of the project delivery method and the contractual approach. A major part of statistics is common to nearly all Mega-projects (\$10 M or more). Including the number of stakeholders and participants involved and the big amount of information generated. Maged Abdelsayed of Tardif compiled the following data. Murray & Associates, a construction company located in Quebec. Canada (Hendrickson, 2003):

- Number of participants (companies): 420 (including all suppliers and sub-sub-contractors)
- Number of participants (individuals): 850
- Number of different types of documents generated: 50
- Number of pages of documents: 56,000
- Number of bankers boxes to hold project documents: 25
- Number of 4-drawer filing cabinets: 6
- Number of 20-inch-diameter. 20-year-old. 50-feet-high, trees used to generate this volume of paper: 6
- Equivalent number of MegaBytes of electronic data to hold this volume of paper (scanned): 3.000 MB
- Equivalent number of compact discs (CD5): 6

It is not easy to manage such a large number of people and documents. Regardless of the contractual approach taken. The following figure illustrates the typical members of a project team and their various organizational boundaries.

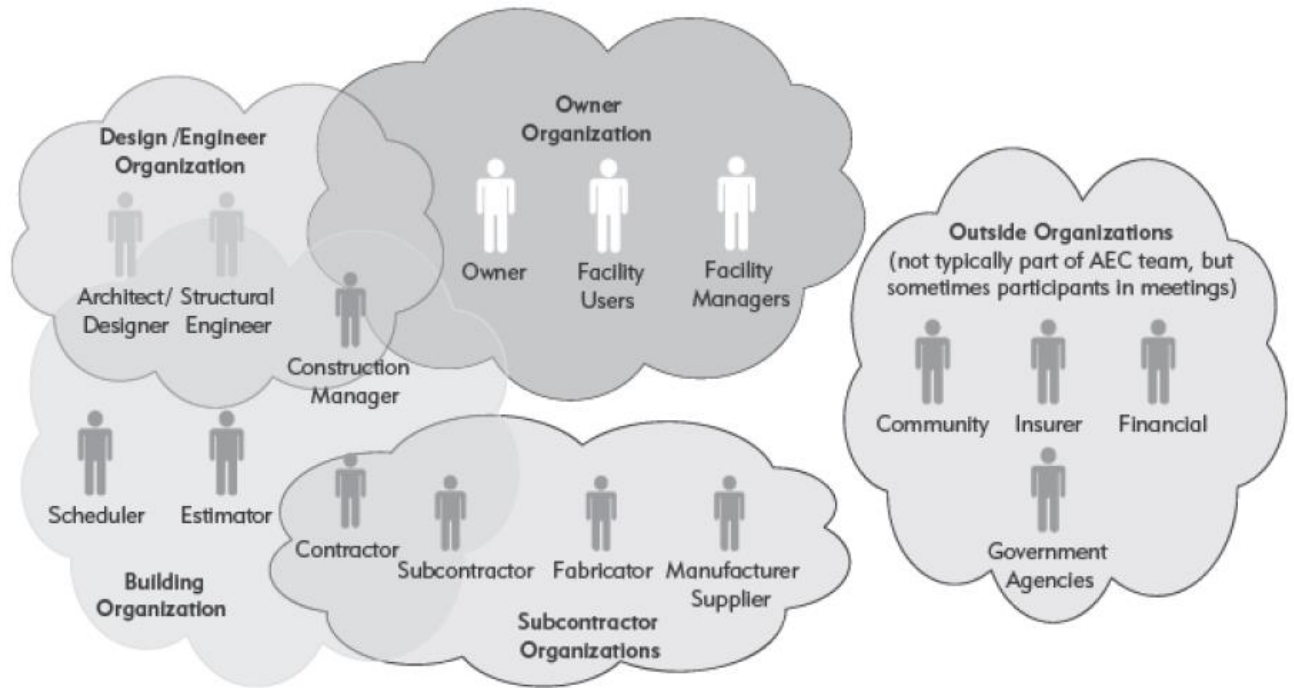


Figure 6 AEC Project team and the common organization boundaries. (Eastman, et al., 2011, p. 4)

There are three dominant contract methods in the United States: Design-Bid-Build. Design-Build and Construction Management at Risk. There are also many variations of these (Warne & Beard, 2005). A fourth method, quite different from the first three, called “Integrated Project Delivery” is becoming increasingly popular with sophisticated building owners. These four approaches are now described in detail.

2.2.2.1 Design-Bid-Build

A significant percentage of buildings are built using the Design-Bid-Build (DBB) approach (almost 90 percent of public buildings and about 40 percent of private buildings in 2002) (Intelligence, 2007). The two major benefits of this approach are: more competitive bidding to achieve the lowest possible price for an owner, and less political pressure to select a given contractor. (The latter is particularly important for public projects.) the following figure schematically illustrates the typical DBB procurement process as compared to the typical Construction Management at Risk (CM at Risk) and Design-Build (DB) processes In the BBB model.

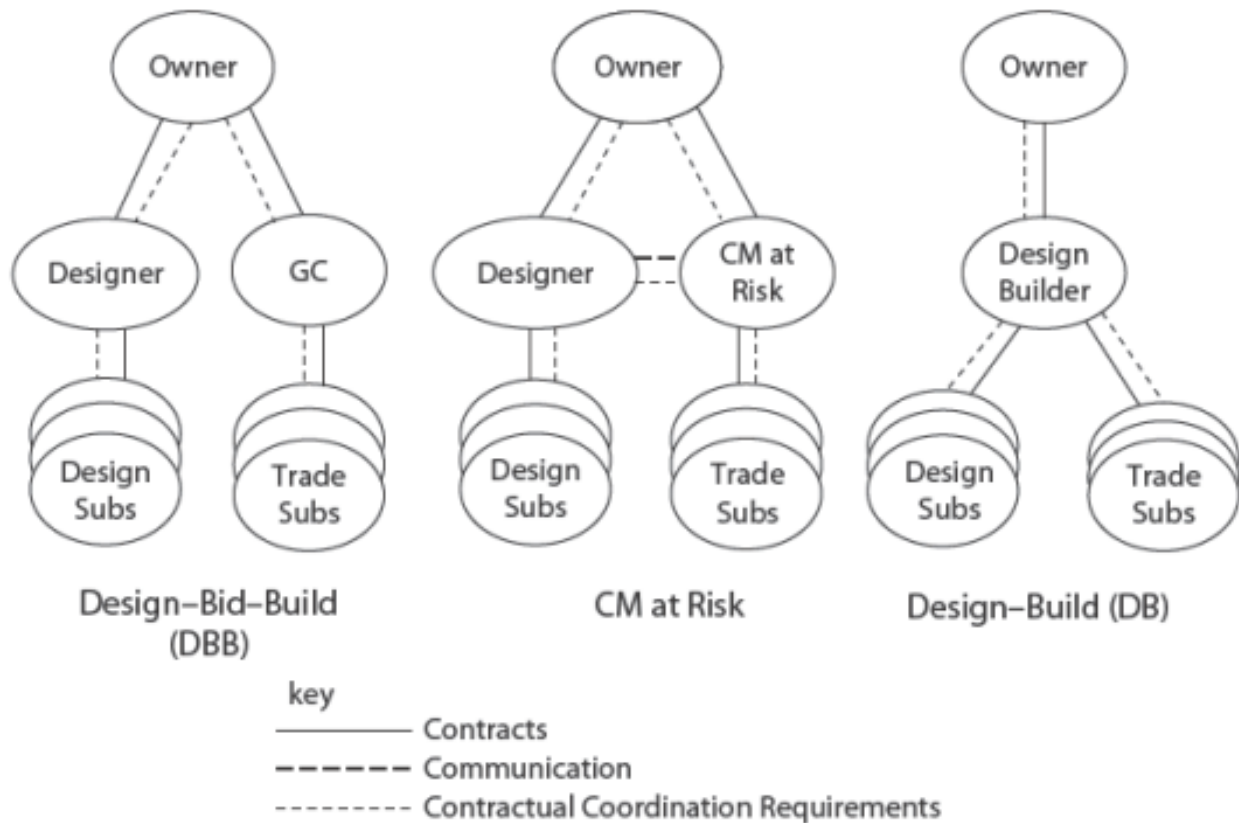


Figure 7 Design-Bid-Build, CM 01 Risk, and Design-Build processes. (Eastman, et al., 2011, p. 5)

Stage one: The owner hires an architect. Who then develops a list of building requirements (a program) and create the project's design objectives. The architect proceeds through a series of phases: Concept design. Design development. And contract documents. The final documents must fulfill the program and satisfy local building and locations or countries codes. The architect either hires employees or contracts consultants to assist in designing structural, HVAC, piping, and plumbing components. These designs are saved on drawings (plans, elevations, 3D visualizations), which must then be coordinated and collaborated together to reflect all of the changes as they are designed to be functional. In the end, a set of drawings and specifications must contain sufficient detail to manage and operate construction bids. Due to potential liability, an architect may choose to include fewer details in the drawings or insert language indicating that the drawings cannot be relied on for dimensional accuracy for example "Don't scale from the drawings" is a very common general comment on my detailed drawings even. These processes often lead to disputes with the contractor, as errors and omissions are detected and responsibility and extra costs reallocated. (Eastman, et al., 2011, p. 5).

Stage two: involves holding a bidding process between general contractors. The owner and architect may set boundaries to determine which contractors can bid. Each contractor must be sent “Financial and technical offers” as a set of drawings and specifications which are then used to develop an independent quantity survey. These quantities, together with the bids from subcontractors and suppliers that the general contractor will hire, are then used to determine their cost estimate. Subcontractors selected by the contractors must follow the same process and approved by the owner and the architect. Because of the effort required, contractors (general and subcontractors) typically spend approximately 1 percent of their estimated costs in prepare and submit the bids. If a contractor wins approximately one out of every 6 to 10 jobs that they bid on the cost per successful bid averages from 6 to 10 percent of the entire project cost. This expense then gets added to the general and subcontractors’ overhead costs. (Eastman, et al., 2011, p. 7)

The winning contractor is usually the one with the lowest responsible bid and with a reliable technical proposal including work to be done by the general contractor and selected subcontractors. Before work can begin, usually it is necessary for the contractor to rearrange and redraw the drawings with more details to present the construction process and the stages of work. These are called general working drawings. The subcontractors and fabricators must also make their own shop drawings to reflect accurate details of certain items, such as precast concrete units, steel connections wall details, piping runs, and the like.

It is necessary to generate accurate and complete detailed drawings extends to the shop drawings, as these are the most detailed representations and are used for actual fabrication. If these drawings are inaccurate or incomplete, or if they are based on drawings that already contain errors, inconsistencies, or omissions, then expensive time-consuming conflicts will arise in the field. The costs associated with these conflicts can be significant especially in the case of Mega-projects. (Eastman, et al., 2011, p. 5)

“Inconsistency, inaccuracy, and uncertainty in design make it difficult to fabricate materials offsite. As a result, most fabrication and construction must take place onsite and only after exact conditions are established. Onsite construction work is more costly, more time-consuming, and prone to produce errors that would not occur if the work were performed in a factory environment where costs are lower and quality control is better.” (Eastman, et al., 2011, p. 7).

Often during the construction phase, many and many changes are made to the design as a result of previously unknown errors and omissions, unpredictable site conditions, the availability of materials in the market, question marks start to pop up about the design, owner new requirements, and new technologies. For each change, a procedure is required to determine the reasons, determine responsibility, estimate time and cost impacts, and address how the problem will be resolved. This procedure, whether instructed in writing or with the use of a Web-based tool, involves a Request for Information (RFI), which must then be answered by the architect or another relevant party. Next, a Change Order (CO) is issued and all impacted parties are notified about the change, which is communicated together with the needed changes in the drawings. These changes and resolutions frequently lead to legal disputes, extra costs, and time delays. Web site products for managing these transactions do help the project team stay on top of each change, but because they do not address the source of the problem, they are of marginal benefit. (Eastman, et al., 2011, p. 9).

Problems are raised up when a contractor bids under the estimated cost in order to get the contract “unbalanced bids are common here”. Contractors usually misuse the change processes to overtake the losses caused by the unbalanced original bid. This, of course, leads to more disputes between the owner and the project team. So the Project Manager “Architect” should refuse the illogical technical or financial bids to avoid such a situation.

In addition, the DBB process requires that the procurement of all materials be held until the owner approves the bid, which means that long lead time items may extend the project schedule. For this and other reasons (described below), the BBB approach often takes longer than the DB approach.

The final phase is testing and commissioning the building, which takes place after construction is accomplished. This involves testing the building systems (heating, cooling, electrical, plumbing, fire sprinklers, and so far) to assure everything is working properly. Depending on contract requirements, as-built drawings are then produced to reflect all as-built Changes, and these are delivered to the owner including all manuals for installed equipment. At this point, the DBB process is completed.

“Because all of the information provided to the owner is conveyed in 2D (on paper or equivalent electronic files), the owner must put in a considerable amount of effort to relay all relevant information to the facility management team charged with maintaining

and operating the building. The process is time-consuming, prone to error, costly, and remains a significant barrier.” (Eastman, et al., 2011, p. 6).

As a result of these problems. The Design-Bid-Build DBB approach is probably not the most expeditious or cost-efficient approach to design and construction. Other approaches have been developed to address these problems.

2.2.2.2 Construction Management at Risk

Construction management at risk (CM@R) project delivery is a strategy for the owner to retain a designer to furnish design services and also to retain a construction manager to provide construction management services for a project throughout the pre-construction and construction phases. Those services may include preparation and coordination of the bidding processes and offers, scheduling, cost control, value engineering, and construction management and documentation. The construction manager is often a certified general contractor and guarantees the cost of the project (guaranteed maximum price, or GMP). The owner is responsible for the design before a GMP can be set. Unlike DBB, CM@R brings the constructor into the design process at a stage where they can have definitive input. The value of the delivery method stems from the early involvement of the contractor and the reduced the responsibility of the owner for cost overruns that can show up later during the construction phase. (Eastman, et al., 2011, p. 7).

2.2.2.3 Integrated Project Delivery

“Integrated project delivery (IPD) is a relatively new procurement process that is gaining popularity as the use of BIM expands and the AEC facility management (AEC/FM) industry learns how to use this technology to support integrated teams. There are multiple approaches to IPD as the industry experiments with this approach”. The American Institute of Architecture (AIA) has prepared sample contract forms for a family of IPD versions (AIA, 2007, p. 1). In all cases, integrated projects are distinguished by effective collaboration among the owner, the prime (and possibly sub-) designers, the prime (and possibly key sub-) contractor(s). (Eastman, et al., 2011, p. 8).

This collaboration takes place from early design phases such as concept design and design development and continues through project handing over. The main concept is that this project team works together using the best collaborative tools “BIM as an example” at their disposal to ensure that the project will meet owner and users expectations at significantly reduced time and cost. Two ways to achieve this, first the owner

needs to be part of this team to assist manage the process, second, the owner hires a consultant to represent his interests, and the best is both may participate. The tradeoffs that are always a part of the design process can best be evaluated using BIM—cost, energy, functionality, esthetics, and constructability. Thus, BIM and IPD go together and represent a clear break with a parallel relation that both are based on paper representation exchange of information. Obviously, the owner is the primary beneficiary of IPD, but it does require that the owner to understand enough to participate and specify in the contracts what exactly needed from the participants and how it will be achieved. (Eastman, et al., 2011, p. 9).

The following table is comparing the traditional project delivery method and the integrated project delivery IPD.

	Traditional Project Delivery	Integrated Project Delivery
teams	Fragmented, assembled on “just-as-needed” or “minimum-necessary” basis, strongly hierarchical, controlled	An integrated team entity composed key project stakeholders, assembled early in the process, open, collaborative
process	Linear, distinct, segregated; knowledge gathered “just-as-needed”; information hoarded; silos of knowledge and expertise	Concurrent and multi-level; early contributions of knowledge and expertise; information openly shared; stakeholder trust and respect
risk	Individually managed, transferred to the greatest extent possible	Collectively managed, appropriately shared
compensation/ reward	Individually pursued; minimum effort for maximum return; (usually) first-cost based	Team success tied to project success; value-based
communications/technology	Paper-based, 2 dimensional; analogy	Digitally based, virtual; Building Information Modelling (3, 4 and 5 dimensional)
agreements	Encourage unilateral effort; allocate and transfer risk; no sharing	Encourage, foster, promote and support multi-lateral open sharing and collaboration; risk sharing

Table 3 Comparison between Integrated Project Delivery and Traditional Project Delivery⁹

⁹ https://info.aia.org/SiteObjects/files/IPD_Guide_2007.pdf (AIA, 2007, p. 1)

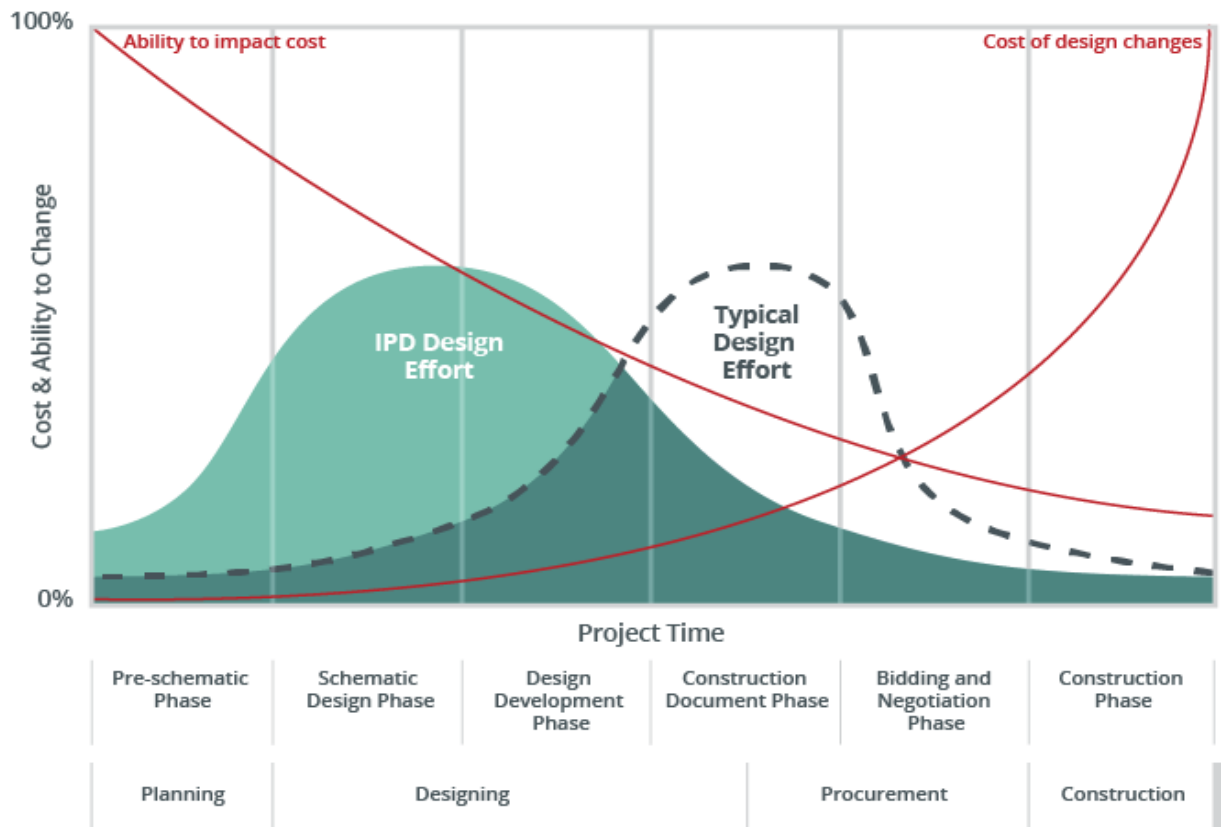


Figure 8 Integrated Project Delivery (IPD)¹⁰

- **Benefits of IPD**

Recent studies document inefficiencies and waste in the construction industry. For example, an Economist article from 2000 identifies 30% waste in the US construction industry; a NIST study from 2004 targets lack AEC software interoperability as costing the industry \$15.8B annually; and a US Bureau of Labour Statistics study shows construction alone, out of all non-farm industries, as decreasing in productivity since 1964, while all other non-farm industries have increased productivity by over 200% during the same period. New technologies have emerged, that when utilized in conjunction with collaborative processes, are demonstrating substantial increases in productivity and decreases in requests for information, field conflicts, waste, and project schedules. Owners are increasingly demanding methodologies that deliver these outcomes. (AIA, 2007, p. 3)

IPD results in greater efficiencies. The United Kingdom's Office of Government Commerce (UKOGC) estimates that savings of up to 30% in the cost of construction can

¹⁰ <http://www.vjscozzariandsons.com/what-we-do/integrated-project-delivery/>

be achieved where integrated teams promote continuous improvement over a series of construction projects. UKOGC further estimates that single projects employing integrated supply teams can achieve savings of 2-10% in the cost of construction (Commerce, 2007, p. 6).

Beyond these benefits, IPD provides positive value propositions for the three major stakeholder groups:

- **Owners**

The owners will effectively balance project options to meet their business organizational goals by early and open sharing of project knowledge streamlines project communications. Integrated delivery assists the project team's understanding of the owner's desired outcomes, which improves the team's ability to monitor and control costs and manage the budget, overall will increase the likelihood that project meets the owner expectations.

- **Constructors**

The integrated delivery process allows constructors to include all their expertise in construction techniques early in the design process resulting in improving project quality and economic performance during the construction phase. The constructor's participation during the design phase allows the chances for strong pre-construction planning, schedule and informed understanding of the design, prediction and resolving design-related problems, visualizing construction sequencing prior to construction start, and enhancing cost control and budget management, all of which increase the likelihood that project goals.

- **Designers**

The integrated delivery process allows the designer to benefit from the early contribution of constructors' expertise during the design phase, such as accurate budget estimates to inform design decisions and the pre-construction resolution of design-related problems lead to enhance project quality and economic performance. The IPD process raises the level of effort during early design phases, causing reduction of documentation time, and enhanced cost control and budget management, overall increase the likelihood that project goals (AIA, 2007, p. 4).

2.2.3 BIM: New Tools and New Processes

2.2.3.1 BIM Model Creation Tools

Historically, All CAD versions and systems produce digital file or plotted documents. It becomes in stages, at the beginning vectors associated to lines in 2D. Then texts were added either independent or connected to the 2D lines and attributes. Then it comes to 3D shapes with labels and attributes creating drawings and all the drawings create the proposed design. Then the creation of blocks of data and complex surfacing tools were founded such as 3D face tools.

As CAD systems became more intelligent and more users wanted to share data associated with a given design, the focus shifted from drawings and 3D images to the data itself, designers and engineers need to share the data related to the drawings and the design more than the shape itself and in CAD systems it had to be written in text next to the drawings as it is a word document. A building model produced by a BIM tool can support multiple different views of the data emerged within a drawing set, for both 2D and 3D. A building model can be described by its content, no need to write the information again next to the design as a text because it is already a part of the design and can be viewed and edited in many ways. The latter approach is preferable because it defines what you can do with the model rather than how the database is constructed (which will vary with each implementation). (Eastman, et al., 2011, p. 15).

The following is both the vision for and a definition of BIM technology provided by the National Building Information Modeling Standard (NBIMS) Committee of the National Institute of Building Sciences (NIBS) Facility Information Council (FIC). The NBIMS vision for BIM is *“an improved planning, design, construction, operation, and maintenance process using a standardized machine-readable information model for each facility, new or old, which contains all appropriate information created or gathered about that facility in a format useable by all throughout its lifecycle.”* (NIBS, 2008).

The scope of BIM directly or indirectly affects all stakeholders supporting the capital facilities industry. BIM is a fundamentally different way of creating, using, and sharing building lifecycle data. The terms Building information Model and Building Information Modeling are often used interchangeably, reflecting the term's growth to manage the expanding needs of the constituency.

The NBIMS Initiative categorizes the Building Information Model (BIM) three ways:

1. As a product
2. As an IT-enabled, open standards-based deliverable, and a collaborative process
3. As a facility lifecycle management requirement.

These categories support the creation of the industry information value chain, which is the ultimate evolution of BIM. This enterprise-level (industry-wide) scope of BIM is the area of focus for NBIMS, bringing together the various BIM implementation activities within stakeholder communities. (Eastman, et al., 2011, p. 16)

BIM moves the industry forward from current task automation of project and paper-centric processes (3D CAD, animation, linked databases, spreadsheets, and 2D CAD drawings) toward an integrated and interoperable workflow where these tasks are collapsed into a coordinated and collaborative process that maximizes computing capabilities, Web communication, and data aggregation into information and knowledge capture. All of this is used to simulate and manipulate reality-based models to manage the built environment within a fact-based, repeatable and verifiable decision process that reduces risk and enhances the quality of actions and product industry-wide. (Eastman, et al., 2011, p. 17)

2.2.3.2 Definition of Parametric Objects

The concept of parametric objects is central to understanding BIM and its differentiation from traditional 3D objects. Parametric BIM objects are defined as follows:

- Consist of geometric definitions and associated data and rules.
- Geometry is integrated no redundantly and allows for no inconsistencies. When an object is shown in 3D, the shape cannot be represented internally redundantly, for example, as multiple 2D views. A plan and elevation of a given object must always be consistent. Dimensions cannot be “fudged.”
- Parametric rules for objects automatically modify associated geometries when inserted into a building model or when changes are made to associated objects. For example, a door will fit automatically into a wall, a light switch will automatically locate next to the proper side of the door, a wall will automatically resize itself to butt to a ceiling or roof, and so forth.

- Objects can be defined at different levels of aggregation, so we can define a wall as well as its related components. Objects can be defined and managed at any number of hierarchy levels. For example, if the weight of a wall subcomponent changes, the weight of the wall should also change.
- Objects' rules can identify when a particular change violates object feasibility regarding size, manufacturability, and so forth.
- Objects have the ability to link to or receive, broadcast, or export sets of attributes, for example, structural materials, acoustic data, energy data, and the like, to other applications and models.

2.2.3.3 What is IFC

IFC (Industry Foundation Classes) is known by most professionals simply as a data model developed by the building SMART (earlier called IAI) to facilitate interoperability in the building industry. Benefits of BIM will take place only through sharing information across organizations, departments, IT systems and databases. IFC standard is the key to validate this cost-effectively and without depending on the product or vendor-specific file formats. Major CAD producers have participated in developing IFC, and their products support it.

“The IFC system is a data representation standard and file format used to define architectural and construction-related CAD graphic data as 3D real-world objects. Its main purpose is to provide architects and engineers with the ability to exchange data between CAD tools, cost estimation systems, and other construction-related applications. IFC provides a set of definitions for all object element types encountered in the building industry and a text-based structure for storing those definitions in a data file” (SOLIBRI INC., 2018).

IFC uses a plain text file, the only truly universal computer data format. Individual CAD developers store data in a product-specific binary file format that best suits their system. The developers provide “Save as IFC” and “Import IFC” commands, which map the IFC object definitions to their CAD system's representations of these objects.

Modern BIM systems are able to create rich internal representations on building components. IFC adds a common language for transferring that information between different BIM applications while maintaining the meaning of different pieces of information

in the transfer. This reduces the need for remodeling the same building in each different application. It also adds transparency to the process. For example, quantities and be taken off at any time during the course of the design and cost can be estimated to see how recent changes have affected the budget. (SOLIBRI INC., 2018).

2.2.4 What is Not BIM Technology?

The term BIM is a popular common word used by software developers to describe the options and modeling abilities that their products offer for builds modeling. As such, the definition of what constitutes BIM technology is subject to variation and confusion. To deal with this confusion, it is useful to describe modeling solutions that do not utilize BIM design technology. These include tools that create the following kinds of models:

- Models that contain 3D data only and no (or few) object attributes. These are models that can only be used for graphics visualizations and have no synchronized information at the object level. They are fine for visualization but provide few or no support for information integration and design analysis. An example is Google's SketchUp application which is excellent for rapid development of building schematic designs, but limited use for any other type of analysis because it has no knowledge of the objects in the design other than their geometry and appearance for visualization.¹¹
- Models with no support of behavior. These are models that define objects but cannot adjust their positioning or proportions because they do not utilize parametric synchronized information. This makes changes extremely consuming time and effort and presents no protection in opposition to growing inconsistent or inaccurate views of the model. (Eastman, et al., 2011, p. 19).
- Models that are composed of multiple 2D CAD reference files that must be combined to define the building. It is impossible to ensure that the resulting 3D model will be feasible, consistent, countable, and display intelligence with respect to the objects contained within it. (Eastman, et al., 2011, p. 19).

¹¹ <https://google-sketchup.en.uptodown.com/windows>

- Models that allow changes to dimensions in one view that are not automatically reflected in other views. This allows for errors in the model that are very difficult to detect and can create major problems when viewing different facades.

2.2.5 What are the benefits of BIM? What problems does it address?

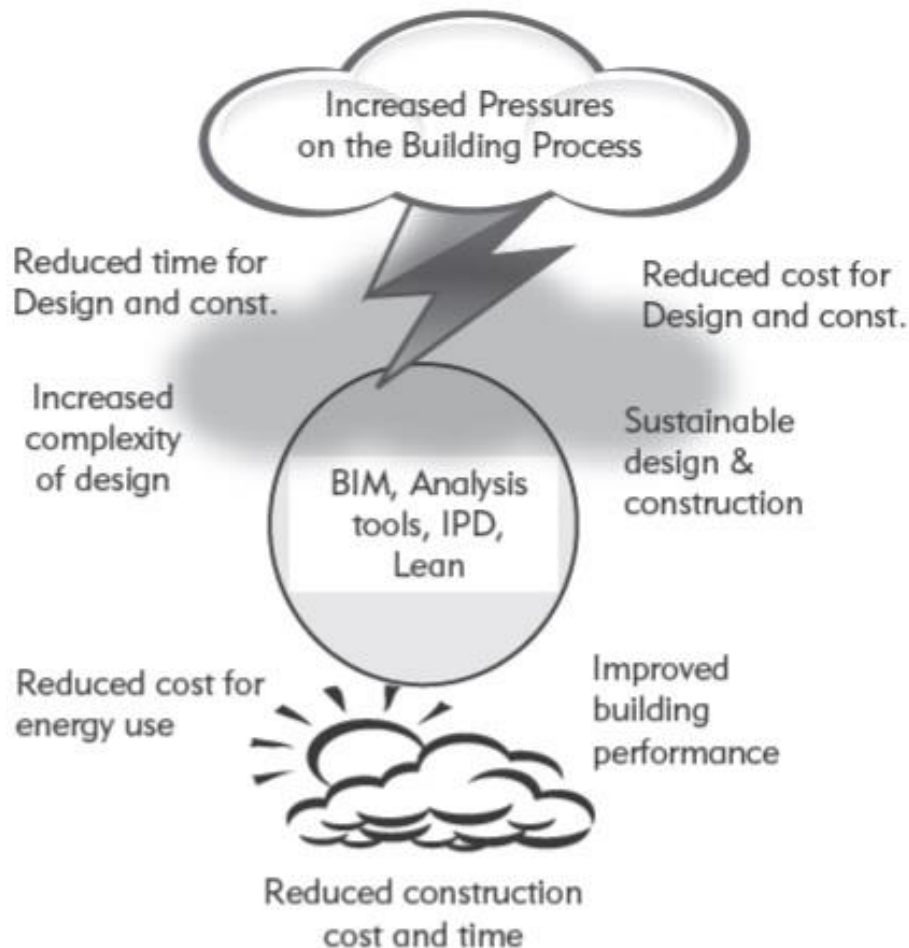


Figure 9-6 BIM technology and associated processes can help to respond to the increasing pressures on a building over its lifecycle. (Eastman, et al., 2011, p. 20)

BIM technology can support and enhance many commercial enterprise practices. Although the AEC/FM (facility management) industry is in the early days of BIM use, significant upgrades have already been realized (compared to regular 2D CAD or paper-based practices). Though it is not going that all of the benefits mentioned below are presently in use. We have listed them to exhibit the whole scope of modifications that can be predicted as BIM technological know-how develops.

The previous figure explains how BIM technology and associated tactics are at the coronary heart of how the building design and construction systems can reply to the

growing pressures of higher complexity for example in Mega-projects. Faster development. Improved sustainability whilst decreasing the cost of the building and its subsequent use. (Eastman, et al., 2011, p. 20).

Traditional exercise is currently not able to reply to these pressures. The coming sections shortly describe the benefits of BIM for owners in preconstruction phase, for designers in design development and detailed design phases, for contractors and manufacturers in the construction phase, for facility managers and owners in post-construction phases.

2.2.5.1 Preconstruction benefits to the owner

- Concept, feasibility, and design benefits

Before owners contact an architect, it is critical to decide whether or not a building of a given size. Quality level and desired program requirements can be built within the frame of a given price and time budget. In different words, can a given building meet the financial expectations of an owner? If these questions can be answered with relative certainty, owners can then proceed with the expectation that their targets are achievable. Finding out that a specific design is significantly over budget after a bigger amount of time and effort has been expended is a waste. An approximate (or “macro”) building model built into and linked to a cost information can be of great value and major assistance to an owner. (Eastman, et al., 2011, p. 20).

- Increased building performance and quality

Developing a schematic model prior to producing a specific building model permits for a more careful assessment of the proposed scheme to decide whether it meets the building’s usages and sustainable targets. Early assessment of design options and the use of analysis/simulation tools will increase the general quality of the building. (Eastman, et al., 2011, p. 21).

- Improved collaboration using Integrated Project Delivery (IPD)

When the owner makes the use of Integrated Project Delivery (IPD) for project procurement, BIM can be used with the aid of the project team from the start of the design to enhance their perception of project targets and to extract cost estimates as the design is progressing. This permits design and cost to be

deeper understood and additionally avoids the use of paper documents exchange and its related delays. (Eastman, et al., 2011, p. 21).

2.2.5.2 Design benefits

- Earlier and more accurate visualizations of a design

The 3D model generated through the BIM software program is designed immediately instead of being generated from a mix of 2D views. It can be used to visualize the design at any stage of the process with the anticipation that it will be dimensionally constant in every view. (Eastman, et al., 2011, p. 21).

- Automatic Low-Level Corrections When Changes Are Made to Design.

If the objects used in the design are managed by parametric rules that ensure appropriate alignment, then the 3D model will be free of geometry, alignment, and spatial coordination errors. This reduces the user's need to control design changes. For example the purge order in AutoCAD to delete the unnecessary layers and objects or lines smaller than a certain length. (Eastman, et al., 2011, p. 22).

- Generation of accurate and consistent 2D drawings at any stage of the design.

Accurate and steady drawings can be extracted for any set of objects or specified View of the project. This significantly reduces the time and number of errors related to generating construction drawings for all design disciplines. When modifications to the design are needed, thoroughly steady drawings can be generated as soon as the design modifications are made. (Eastman, et al., 2011, p. 22).

- Earlier collaboration of multiple design disciplines

BIM technology helps simultaneous work by all design disciplines at once. While collaboration with drawings is additionally possible, it is historically extra difficult and time wasting than working with many coordinated 3D models in which change control can be well coordinated. This reduces the design time and mainly reduces design errors and omissions. It also gives earlier perception into design troubles and gives possibilities for a design to be always improved. *"This is much more cost-effective than waiting until a design is nearly complete and*

then applying value engineering only after the major design decisions have been made.” (Eastman, et al., 2011, p. 23).

- Easy verification of consistency to the design intent

BIM technology assists earlier 3D visualizations and turning the area of spaces and other material to quantities and number, giving the chance to earlier and more accurate cost estimates. For technical buildings (labs, hospitals, and the like), the design purpose is frequently determined quantitatively, and this permits a building model to be used to check for these requirements. For qualitative requirements (those spaces should be next to each other), the 3D model also can support automatic evaluations. (Eastman, et al., 2011, p. 23).

- Extraction of cost estimates during the design stage

In all the design stages BIM technology has the ability to provide a bill of quantities and/or dimensions, areas, volumes or any other parameters of the model components. In the early stages of a design like concept design, cost estimations are primarily based on both formulas that are connected to significant project quantities, for example, the number of parking spaces, square meters of office areas of various types, and unit costs per square meter. As the design progresses with more information and details are involved, more accurate quantities are available and can be used for more accurate and detailed cost estimates. It is possible to keep all participants and stakeholder's conscious of the cost inclusions related to a given design before it develops to the level of detail required of the construction bidding process. At the final stage of design, cost estimations based on the quantities for all the components included within the model permit for the preparation of a more accurate final cost estimation. As a result, it is possible to make more knowledgeable design decisions regarding costs using BIM rather than a paper-based system or 2D drawings for CAD systems. When using BIM for cost estimates, of course, it is an advantage to have the general contractor and hopefully subcontractors who will be responsible for building the structure, as part of the project team. Their know-how is required for accurate cost estimates and constructability insights throughout the design process. (Eastman, et al., 2011, p. 23).

- Improvement of energy efficiency and sustainability

Connecting the building model to energy analysis tools allows analysis of energy usages through the early design development phases. This is no longer realistic using traditional 2D tools due to the fact of the time required to prepare the applicable inputs. If utilized at all, energy evaluation is carried out at the end of the 2D design procedures as a test or a regulatory requirement, therefore decreasing the chances of changes that could enhance the building's energy performance. The ability to link the building model to different types of analysis tools provides many possibilities to enhance building quality. (Eastman, et al., 2011, p. 23).

2.2.5.3 Construction and Fabrication Benefits

- Use of design model as a basis for fabricated components

If the BIM design model is transferred to a BIM fabrication tool and more details were added to reach the level of fabrication objects (shop drawing model), it will include an accurate illustration of the building components for manufacturing and construction. Due to components are already detailed in 3D, their automated manufacturing using numerical control machinery is simplified. For example, automation is trendy exercise today in steel fabrication and some sheet metal work. It has been used effectively in precast concrete components, Windows, doors, and glass fabrication. This allows manufacturers and suppliers all over the world to precise on the model, to produce details needed for fabrication, and to hold connections that reflect the design purpose. This allows offsite fabrication and decreases cost and construction time. The accuracy of BIM additionally permits larger elements of the design to be fabricated outside the project site that would generally be tried using 2D drawings, because of the possible need for onsite modifications "rework" and the incapacity to anticipate precise dimensions until other elements are built in the field. It as well permits smaller installation groups, quicker installation time, and much less space need in the site to store materials. (Eastman, et al., 2011, p. 24).

- Quick reaction to design changes

The influence of purposed design modifications and changes can be inputted into the building model and changes to the different objects in the design will

automatically update. Some changes will be made automatically based on the established parametric rules "Auto-correction level". Also, some updates can be done due to the clashes founded between different design disciplines. The results of a change can be exactly reflected in the model and all related views of it. In addition, design changes can be resolved faster in a BIM system because modifications can be shared, visualized, estimated, and resolved without the need of paper documents which is not the best use of time. All modifications with this system are more accurate and easier than in paper documentation systems. (Eastman, et al., 2011, p. 24).

- Discovery of design errors and omissions before construction

The BIM model is the source of all 2D or 3D drawings and any modifications done in the model will be reflected in all the drawings at once which eliminates the chance of conflicts between 2D drawings. Also, it is easier to bring all the disciplines in one model or one drawing and discover the conflicts between them, and find the best modification that can be done to coordinate all disciplines together. Conflicts and construction problems are determined and highlighted before it can be constructed in the field. Coordination between involved architects, engineers, managers and contractors is enhanced and errors of omission are decreased. Which saves time and reduce the construction process, decrease time, reduces costs, reduce the similar expected legal disputes, and assist a smoother process for the whole project team. (Eastman, et al., 2011, p. 25).

- Synchronization of design and construction planning

Creating a link between the 3D model and the project schedule plan gives the option to view how the building would look like in any construction point of time or even it can create a simulation of the construction process itself which can allow the stakeholders to discover future problems which were not addressed before. This 3D model simulation provides a better vision for how the building will be structured day-by-day and show the roots of future problems and chances for possible enhancements (site, project teams, and equipment, areas conflicts, health and safety problems). This type of evaluation is not available from 2D drawings which is a part of the bidding documents. On the other hand,

when the project plan is connected to the BIM model, it can assist the required formwork, shoring and any preparations for the construction process. (Eastman, et al., 2011, p. 25).

- Better implementation of lean construction techniques

Lean construction strategies require cautious coordination between the general contractor and all subcontractors to make sure that work can be carried out when the suitable sources are reachable onsite. This minimizes wasted effort and reduces the need for onsite material inventories. Because BIM offers an accurate model of the design and the material sources required for every phase of the work, it offers the groundwork for extended planning and scheduling of subcontractors and helps to make sure just-in-time arrival of people, equipment, and materials. This reduces cost and permits for higher collaboration at the job site. The model can additionally be used with wireless handheld computer systems to facilitate material tracking, installation progress, and automatic positioning in the field. (Eastman, et al., 2011, p. 25).

- Synchronization of procurement with design and construction

When the BIM model is completed, it can give all the required quantities for all components in the project. These quantities, specifications, and properties can be used to make the purchase orders and coordinate the supplement proceeds with subcontractors and suppliers (for example wooden works manufacture because wooden works are expected to take longer time in the factory). The object details for many manufactured components still not yet been developed to make this capability a complete reality. But, when the models have been available (steel members, precast concrete members, some mechanical components, some windows, and doors), the results have been very applicable. (Eastman, et al., 2011, p. 25).

2.2.5.4 Post Construction Benefits

- Improved commissioning and handover of facility information

At the last part of the construction phase or before in earlier stages, the general contractor try to coordinate the systems together and check the functionality and the integration of the whole building systems specially MEP and IT systems, additionally this process can be checked by BIM models at the end of the design

phase itself, it clearly that those benefits are very valuable for the owners and the contractor to make sure that everything is working flawlessly before the operation phase. (Eastman, et al., 2011, p. 25).

- Better management and operation of facilities

The building model gives a supply of information (graphics and specifications) for all systems used in a building. Previous analyses used to decide mechanical equipment, manage systems, and different purchases can be supplied to the owner, as an ability for verifying the design choices as soon as the building is in use. This data can be used to take a look at that all systems work correctly after the building is completed. (Eastman, et al., 2011, p. 25).

- Integration with facility operation and management systems

A building model that has been up to date with all modifications made throughout construction affords a correct supply of data about the as-built areas and systems and offers a beneficial beginning point for managing and operating the building. A building information model helps to monitor real-time manage systems, offers a natural interface for sensors, and remote operating management of facilities. Many of these abilities have no longer but been developed, however, BIM presents a perfect platform for their deployment. (Eastman, et al., 2011, p. 26).

3 . BIM implementations in Mega-projects

3.1 BIM impacts and outcomes

The BIM Industry Working Group indicates that there are essential organizational impacts through BIM implementation for all stages of the construction process. (Britain, 2018). Stakeholder collaboration expands organizational boundaries which enhances the performance of the project organization during the design and construction process. (Arayicia, et al., 2010, p. 190). A further impact demonstrates the need when implementing BIM, to change business processes in addition to the simple promotion technology. BIM implementation may impact on all the processes within the project organization and therefore cannot be treated in isolation as a software tool. It, therefore, may be defined as a process related rather than simply technology and that both approaches require BIM to be managed holistically (Björkb & Christer, 2008, p. 271). BIM is a more accurate way of working. As the processes change BIM will reduce waste (materials, resources & cost) through improved designs and construction processes (Azhar, 2011, p. 2). The successes of BIM in creating more sustainable communities. Another key aspect leading to similar improved accuracy, design, and construction is 3D visualization (Nawari, 2012, p. 110) (Eadie, et al., 2013, p. 2).

However, to have a successful implementation of BIM processes, all members of the construction team need the security of confidential data external and internal to the BIM model. The BIM model can be part of an extranet (Christensen, et al., 2007, p. 191). However, this may lead to legal issues. There is the need to deal with the legal issues through the construction contract in order to reduce this significant risk (Udom, 2012).

The significance of the cost of implementing BIM in terms of resources and training has been seen to act as an essential barrier within the construction industry. Regardless of the significant cost of implementation of BIM will ultimately be driven by clients (Crotty, 2013, p. 15). The adoption becomes a requirement then training must be subsidized by the Government to facilitate implementation. The size of the organizations implementing BIM is a significant factor it is easier to implement BIM within the client or supply-side SMEs "*Small and medium-sized enterprises*" however it may be beyond the reach of some SMEs due to its cost (Hore, et al., 2011, p. 26).

3.2 The financial benefits of BIM to the parties involved

The literature review is showing that financial benefits can be achieved through BIM adoption. Analyzing the savings by company size. Two-thirds of BIM users have reported a positive return on investment on their overall investment in BIM (Jardim-Goncalvesa & Grilob, 2009, p. 390). The BIM Industry Working group¹² indicates that the financial savings can be achieved over all the stages of the project lifecycle. The operation and maintenance of the building, the role of the Facilities Managers, equates to 60% of the overall costs of the project (Akcamete, et al., 2010, p. 5). Also to achieve greater financial gains, this concepts can be implemented from the early beginning in the project. *“The main cost savings through the increased interoperability of the BIM software could result in clients and building users/occupants/ operators saving up to two-thirds of the overall \$15.8 billion per year spent in Australia”* (Furieux & Kivvits, 2008). The financial saving can be achieved when the consultants start the work with fully BIM environment and the project follow the same concept till the operation phase (Jingfeng, et al., 2009, p. 255). General contractors and Specialist Contractors determined a reduction of 1%–2% of cost of Mechanical, Electrical and Plumbing Engineering (MEP) systems on a large size healthcare project, this percentage is not a small amount of money in case of 1 billion mega-project (Khanzode, et al., 2008, p. 230). Manufactures and suppliers also have benefits from the accurate cost estimates and more details specifications. Additionally the construction industry benefitting in relation to costs, Software programmers are also shown to have a large return on investment from BIM implementation (Becerik & Rice, 2010, p. 200).

3.3 Project Execution Plan use for BIM projects

The implementation of BIM at some stage in the project lifecycle is usually laid down in a BIM Project Execution Plan (PEP). The BIM PEP identifies the place the most benefits of BIM can be accomplished throughout the planning, design, construction and operational phases of a project. This plan presents an overall application to ensure that all organizations in the design and construction groups are totally cognizant of their duties related to BIM implementation in the venture workflow. Once the plan is created the development towards this plan is monitored to achieve the most benefits

¹² <https://www.cdbb.cam.ac.uk/>

from BIM. It is an essential success aspect in the management of BIM to supply greater ranges of project performance. (Marzouk, et al., 2013, p. 6).

3.4 BIM information provided at the end of the project

Although the Construction, Design and Management regulations in the UK specify that as-built drawings and project historical information are handed at the end of the contract. The majority of accomplished projects contains as-built drawings rather than as-built information which is a different meaning, for example MEP works and infrastructure works before it is the most critical for post-construction activities, the 2D plans can be founded, but not information need to make a maintenance or renovation plan, then extra investigation is needed for the building. This information is usually provided as 2D information only. However, with the advent of BIM, they further suggest that to develop a 3D as-built model was currently more time to consume than traditional 2D as-built however, it could be supplied (Goedert & Meadati, 2008). When providing a separate BIM model for each disciplinary at the end of the construction phase, it means that the facility manager has to coordinate the model somehow which gives the chances to conflicts of information or misinformation, However providing one BIM model for all the disciplines in the project is working like a data bank for the facility manager make it easier to collect the information needed and ensure that this information is coordinated as well. (Eadie, et al., 2013, p. 5).

3.5 AEC industry KPI/metric measurement

The whole benefits of BIM needs to be determined over the lifecycle of the project to ensure that continuance enhancement can be achieved. The performance measurement as a main element of efficiency. Generally, in construction, the headline Key Performance Indicators (KPIs) are employed. The use of KPIs allows schemes to be benchmarked against similar schemes to identify standards in the national performance of the construction industry and identify areas for improvement (Kim & Huynh, 2008, p. 760) (Kagioglou, et al., 2010, p. 90) (Eadie, et al., 2013). The following KPIs should consider systematic performance improvement and determine the following general list for the construction industry “this list in to evaluate the whole project lifecycle in AEC industry not only for BIM”:

- Client satisfaction with the product.
- Client satisfaction with the service.
- Defects.
- Predictability of cost.
- Predictability of time.
- Profitability.
- Productivity.
- Safety.
- Construction cost.
- Construction time.

Those KPIs are for evaluating the whole project life cycle in the AEC industry, however, it can be applied as one package for BIM as well or not, in the coming analysis in the thesis, the benefits of BIM by stages will be considered as those benefits already includes the above mentioned KPIs. The KPIs generally allow comparison between the actual and estimated performance on the basis of three factors, effectiveness, efficiency, and quality. (Eadie, et al., 2013, p. 5).

3.6 Reasons for not implementing BIM in projects

Through the literature review to figure about the reasons for not using BIM, as discussed before that some mega-projects were done without including BIM, however currently BIM is involved maybe not as a full system, but at least partially in all mega-projects, the following results were the most common reasons for not using BIM in the AEC industry:

- Lack of expertise within the project team.
- Lack of expertise within the organizations.
- Lack of owner demand. “The owner demand for BIM”
- Cultural resistance. “Traditions VS innovation”
- Investment cost. “How much does BIM implementation cost?”
- Lack of additional project finance to support BIM. Using a parallel approach to implement BIM while working on the same project with traditional methods, what will be the reason to add more costs to the project budget?

- Resistance at the operational level. Lack of expertise in the post-construction phases, the information is available in BIM models, but the facility management team doesn't have the knowledge to use it.
- Resistance of team members to share information. Team communications with the owner were negatively affected on 8% of occasions and between the team on 5% of occasions by the adoption of BIM. (Leicht, et al., 2007)
- Lack of immediate benefits from projects delivered to date (Eadie, et al., 2013, p. 147). In the countries where the material cost is significantly higher than the labor cost and there is no big margin of labor rights, it was founded that the value of time is less compared to the countries where the labor cost can be higher than the material cost and there are more laws to protect the labor rights.¹³
- Legal issues around ownership, professional indemnity insurance. (Eadie, et al., 2013, p. 147).

3.7 Related case study “Airports as Mega-projects”

3.7.1.1 Airport projects as a Mega-project case study.

Airports reported that benefits through BIM-offered better information are noted increased in constructability and enhancing building performance. BIM, the digital representation of the physical facility can provide better early detections of problems that might result in increased costs related to changes in construction or operation. At Organization Level, BIM is also being utilized to document the current condition of Airports to share this information with teams of future projects. (McCuen & Pittenger, 2016). Performance metrics used by some participating airport to evaluate the BIM Return on Investment (ROI) are listed below:

- Minimizing design omissions and errors
- Minimize Request for Information during construction
- Reducing initial and lifecycle costs
- Shorter duration of construction
- Comparing previous BIM projects to current BIM projects in terms of lifecycle performance. (McCuen & Pittenger, 2016)

¹³ Author

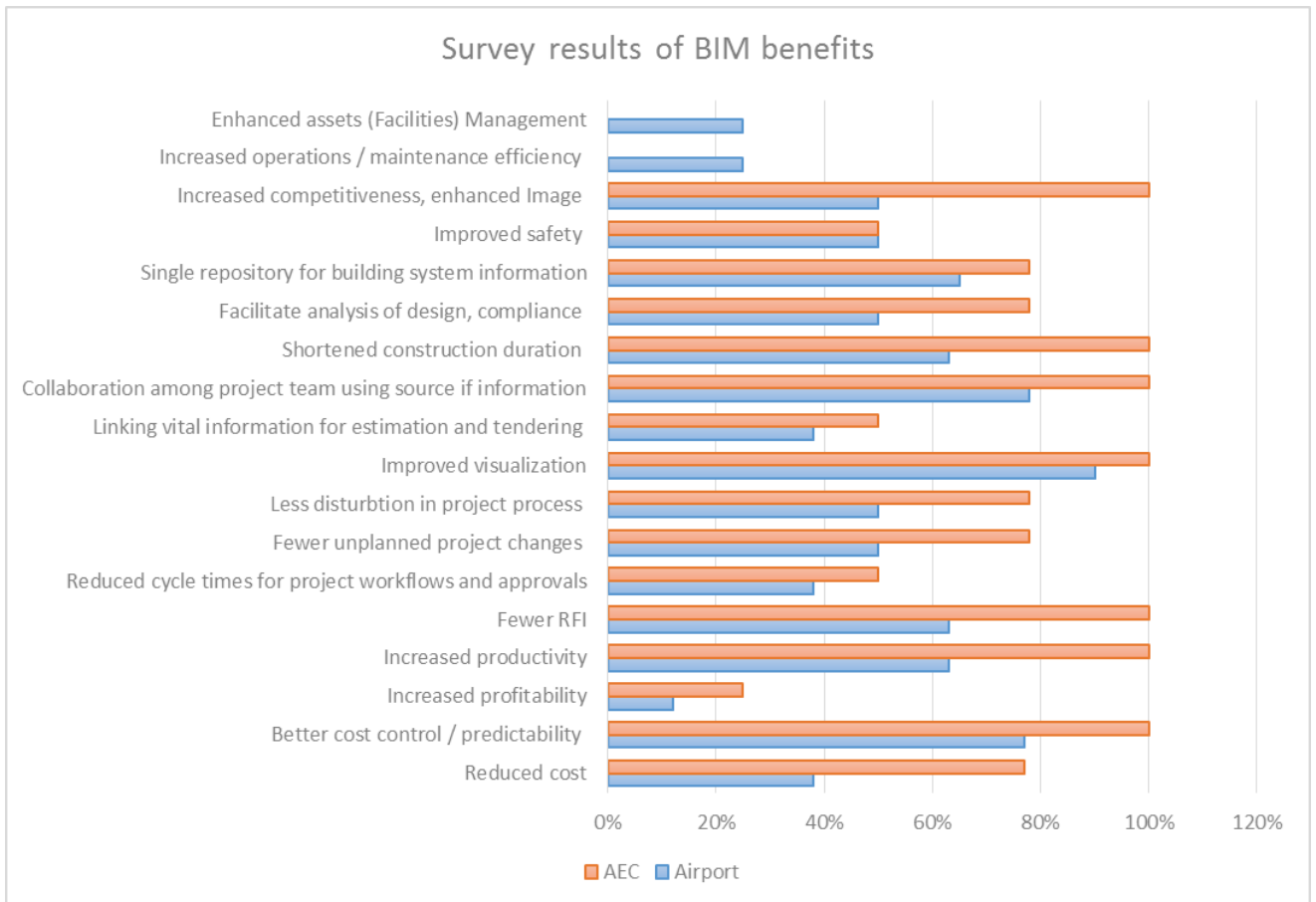


Figure 10 Survey results of BIM benefits in Airport project comparing to AEC project. (McCuen & Pittenger, 2016).

From the previous figure, it is noticeable that the benefits of BIM in airports as an example of mega-projects getting a higher percentage than other AEC projects and this percentage is variance from 10% to 25%. Participating Airports focused on the number of different directions to assess ROI. One participant Airport reported a positive ROI owing that BIM does not necessarily increase the project cost. BIM can accumulate the overall savings of the projects. The routine use of BIM by designer and owner can reduce the project comparing pre-BIM and post-BIM data. The same participant reported that with the help of BIM, it was possible to determine the cost of the corrective maintenance against the cost of preventative maintenance. The participant Airport is to take measures aiming to reduce the cost of the corrective maintenance.

Another Airport reported the difficulty to estimate BIM ROI as BIM implementation is affecting many airport operations. Providing better initial information to project team and politely effecting the quality of a project was is another benefit participating Airport found difficult to quantify. (McCuen & Pittenger, 2016).

3.7.1.2 BIM in Airport Project construction phase

- **Airport project lifecycle**

Airport projects have the most of disciplines in the construction industry and they are not separated or working independently, each discipline is integrated otherwise with one of the other disciplines or with several disciplines. Disciplines can be grouped in the following principle: Architectural, Civil, Survey and structural, Infrastructure, Electrical, Mechanical, Special systems and IT systems. And each of the mentioned disciplines includes a group of work packages which will discuss later with more details.

The airport project life cycle can be divided into work phases as the following: Design development, detailed design, Shop drawings & calculations, Procurement, Construction, testing & commissioning, as built, experimental period, Facility Management & Maintenance and Rehabilitation & Expansions.

- **Design development**

At the early stages of Design development, the airport can be a new airport or an extension for an operated airport, in this stages the relations and links between them are highly needed, we can imagine if the operated airport has a 3D model or even a BIM model, which can include much information about all disciplines that will be linked during the construction phase such as the passengers routes between terminals, the baggage handling system, fuel lines and aircrafts positioning in airside. In Design development stage, a basic level of details in the BIM model to study Runway is required, as it depends on conditions such as wind directions and size, elevation, and obstructions in the area. Benefits of BIM implementations are unlimited. A BIM or at least a 3D model for the surrounding area of the airport project, the airplanes landing paths and noise are controlling how far should be the airport from the residential area. Creating landing paths for airplanes within the BIM model of the urban surrounding area make it possible to decide the best location for the runway. For the terminal design, there are two basic considerations, the first one is the terminal link to the runways and the link to outside roads. The second one is passenger's route inside the terminal and the baggage handling system, which will arrange the check-in counters and the baggage reclaim hall.

- **Detailed design**

Previously before the introduction of BIM, in the detailed design phase, a list of full requirements and tasks is prepared. The list is divided into two categories: (Drawings & Information), Drawings such as overall layout, road layouts, and landscape, operational flows, horizontal and vertical circulation routes, standard and non-standard room layouts, building dimensions and gridlines, Architectural plans sections and elevations of buildings and information such as, accessibility requirements, schedules of accommodation, room data sheets, Finishes schedule, Doors and ironmongery schedules, Sanitary fittings schedule and room signage schedule. On the other hand in the structural detailed design, a lot of details are needed such as, the location of all structural elements corresponding to gridlines, dimensions and sizes of (beams, columns, walls and slabs), details of erection and proposed fixings, loading allowances for each floor slab, The proposed discipline for all holes giving range and sizes, a specification including total weights of reinforcement, The detailed design should highlight any changes from the concept design, and provide MEP & other services engineers with the needed information and coordinate with them.

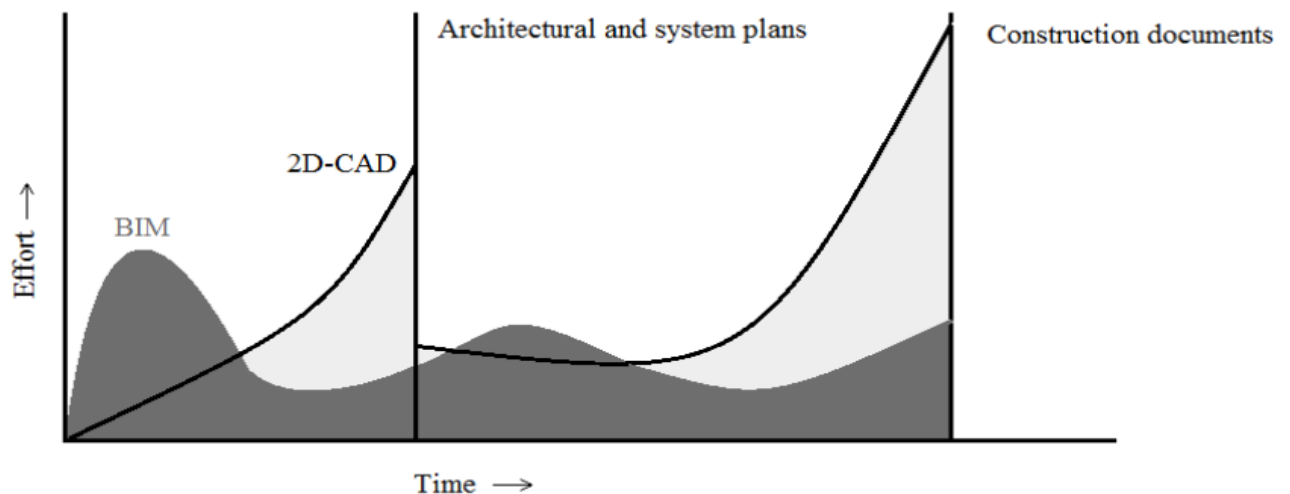


Figure 11: Effort-Time impact of BIM (BIRGING & LINDFORS, 2014)

Throughout the detailed design phase, and in the presence of many disciplines in the airport project, which requires a continuous coordination and the accuracy to discover most of the clashes between them before issuing design drawings to construction, the causes of clashes are to be considered. System clashes are most common. An HVAC duct or pipe penetrating through a structural element. A work schedule clash where two or more activities are scheduled to a certain sequence is found to be parallel or in

reverse order are also noticeable changes or missing schedule updates were also seen. Manual clash detection is a very demanding and time-consuming task. With the introduction of BIM, the process is now semi-automated.

Clash detection before construction is cost-effective, any extra costs that may arise from clashes between systems, or schedule delays caused by holding the work until a solution is found, are avoided. It was found out that in airport design, one of the most common clashes are seen the baggage handling system and other conveying systems with the structural elements. It is imaginable, giving the complexity of the network of conveyor belts are going longitudinally through the entire terminal, also moving vertically through different levels.

Throughout the detailed design phase, the current documentation process in constructions is performed by two or more systems, one program to mark-up and another program for file sharing. The high volume of printing is also involved sometimes which can be seen as an additional strain on both resources and the environment as well. Human errors cannot be ruled out in a manual process, costly mistakes are taking place sometimes.

The way the other programs are working is insufficient, as the most popular application for mark-ups, is Microsoft Excel, which requires a longer time to check all the documents which were sent and received, and when you want to change the statuses for a document, you have to mark-up it again and if the work is going between a group with a shared file, there is a high risk to lose data.

As the airport project usually has a high volume of documents, and numerous revisions. Typically large man-hour investment is required to organize data manually. BIM documents solutions give a significant tool, which allows making mark-ups under any circumstances, at the same time, BIM allows the objects to be visible, which makes the selection process much easier.

The real impact of BIM tool can be noticed when, the whole project group is working from the right form of archives and plans, A cloud-based administration - available at the desktop or cell phones - to convey anyplace, at whatever time community oriented access to the whole project group, delivers a solid tools for preparing, reviewing, approving and publishing all project plans, models and documents from the earliest phase of a project through the whole life cycle for the project.

- **Construction phase**

When it comes to construction kick off, the first obvious operation is mobilization and work site traffic flow, this is an important stage in such a mega project as an airport, which can save hustle or even keep higher levels of safety in the construction site, hereby the BIM give an great 3D tool to make a movements and traffic model for the construction site to simulate the movements routes, tower cranes, material storage locations and people paths into the whole site and also can find out in advance, the predictable red zones at site, which can be mitigated earlier, to save materials or even people life.

Using BIM during the construction phase of a project saves penalty of time, which is corresponding to reducing the total budget cost of a project, especially in projects with complicated designs such as airports, which have several facilities and complicated geometrical designs with information integrated with three dimensions models, also provides two directions data exchange environment between several software applications.

In airport project, creating coordination shop drawings for the baggage handling system with other disciplines is nearly an impossible target, due to the complicated designs and paths for the baggage handling system in the project, which sometimes needs several scenarios and a case study for each one separately, the same also with the scheduled time to install this components, because of it is sensitivity and the rush to construct in order to start testing, in this case, BIM is a significant step to another level of simulation and coordination.

Starting the construction phase doesn't mean the end of shop drawings phase, due to the frequent modifications in Design, which required a modifications in the previous shop drawings or even a new one, with one BIM model for design and shop drawings, any changes will be modified immediately in the model and in the shop drawing also, maybe that will be the only step required to resubmit the shop drawing. In such mega projects delivery of information between the project parties is a critical and difficult task, but with only one BIM model which prevent data losing, achieve a much higher level of coordination and information distribution to all project parties.

During the construction phase, there are interim payments have to be prepared and submitted, according to the work done in site, which takes longer time and needs accuracy to take off the exact done quantity of each item, the updated BIM model gives a whole situation at site for each item showing the on-going and completed items, also its exact quantities, avoiding human error in taking off quantities and penalty saving of time. BIM in this stage giving a brilliant advantage by visualization of interim payments corresponding to the construction works going-on site on a certain cut-off date. This is an essential tool for any successful cost control engineer or a quantity surveyor.

BIM as a visualization tool in such complex mega-projects is an essential presentation tool for a planner, which is giving the maximum capacity of information needed in any report. For any give stakeholder meeting, a planner may require to prepare two full reports of activities lists, which may take a considerable amount of time and efforts to prepare. An up to date BIM model offers the required information at ease. Scheduled activity and actual activities are presented comprehensively for all stakeholders of different backgrounds.

Form the organizations such as the main contractor and the consultant's point of view, as they are the assigned and authorized sides to handle all the design, shop drawings, cost control, planning and documentation tasks in all the project phases, BIM implementations in such complex mega-projects has reduced the required human resources, such as engineers and draftspersons to more than the half in case of using 2D drawings applications, also saved a penalty of time in the early project phases where more human resources where needed.

For Architects and Engineers involved in such complex mega-projects as an airport, it is required to design and prepare details for the suspended ceiling includes all the services hidden above it, as the airport includes more disciplines than any ordinary buildings. It is taking much more effort and a higher level of coordination between more than ten disciplines to create a reflected ceiling plan and details for each zone in the airport, the work cannot be done in the site without such coordination drawings. During this process, changes are more likely to happen with more than one discipline, due to the clashes discovered otherwise during the design stage or constructions. BIM has achieved a significant level of accuracy in producing such drawings, which needs design for the main lines, detailing for each discipline, requirements and method of statement for each activity, clash detection between all the disciplines in the zone, finally

sending those reflected ceiling plans to each team to start working on site with a well prepared and coordinated data, which saves penalty of time and wasted costs that can negatively impact the project budget in a critical stages.

The handing-over of the construction stage is the last 10% of this stage and the most critical one, it requires a snag list of each item, including the testing and commissioning, and integration between the whole systems of the airport, hereby BIM brings it visual and ready with all the information about each item, which is highly needed in this stage. The effort required to finalize this 10% in the handing-over stage maybe is equal to the effort done for the 90% previously. Creating a punch list for the whole project to check what the remaining activities in all disciplines are a demanding task in such complex projects. BIM can easily detect the remaining part of any item, which makes information available for the construction team in this critical phase of the projects when the time is running out and all the stakeholders are waiting for the operation of the airport.

3.8 Interference of Costs, Influence, and information

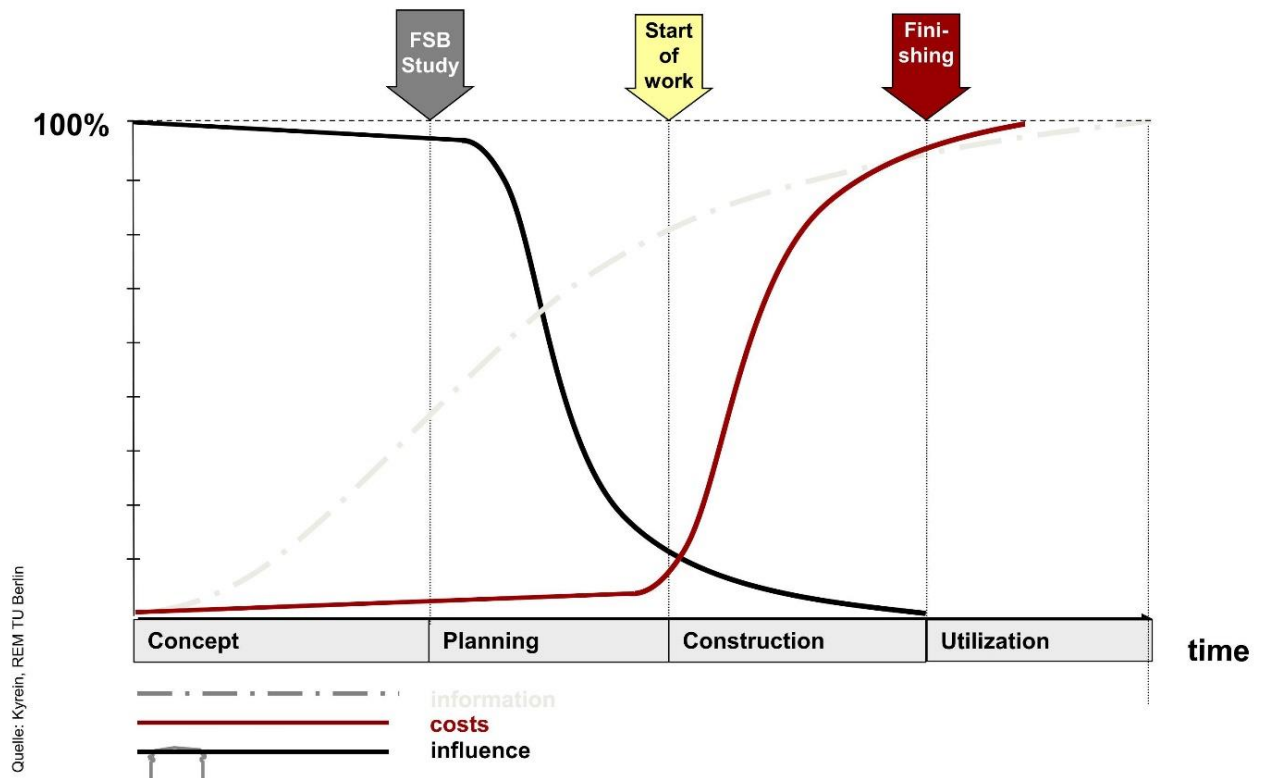


Figure 12 Interference of Costs, Influence, and information¹⁴

- **Information**

Information is at the minimum level in the concept design phase since it is the phase of collecting the information need to take the project decision, in the phase BIM given the advantage to visualize many options with minimum effort comparing to the traditional design methods, after the feasibility study is done and the decision had been made to start the detailed design “planning” phase, the level of information is starting increasing as long as it is heading to the construction phase and through the construction phase the level of information is still growing till it reaches the maximum at the start of utilization and operations, not at the end of construction phase because in any project some modification and improvements are expected to be done with the start of utilization.

- **Costs**

It is obvious that costs curve is starting from day zero of the concept design, however, it is booming with the start of the construction and this is due to the huge budget of

¹⁴ Introduction PD & PM Real Estate Development Process, Prof. Dr.-Ing. Nicole Riediger

construction phase comparing to the whole design and planning phases. In some projects, the operation and utilization phase can be more costly than the construction phase in the project lifetime, but it will be only as estimation, not aggregate information.

- **Influence**

In this chart the influence means the influence of the owner to still have the ability to make changes, however, in reality, the owner can make changes whenever he wants but with the corresponding cost which sometimes can overcome the project budget, hereby only the ordinary case is meant, when the corresponding cost hold back the owner decided to change any detail in the project. It is obvious that in the design phases the cost of change will be the architects or engineers extra fees and the delay time of starting the project, however when the construction starts the corresponding cost to the changes became significantly higher due to the removal of the work already done, the costs of labor, material and time lost in those modifications, so the owner is comparing between the changes versus the costs of this changes both time and money wise. Unlikely what is the curve is telling that the influence is ending to zero at the beginning of utilization, there is still a slight probability that the owner decides to change the purpose of the building which depends on the market and the economic atmosphere when construction is done.

4 . BIM Benefits – Mega-projects Problems Matrix.

4.1 Introduction

In this chapter, a Matrix between BIM benefits through the project life cycle, considering those benefits from Owner, Designers, Contractors and facility managers' point of view and Mega-projects common problems, those problems were founded through the history of this type of projects and the researchers who use those historical events in their previous researches.

From this Matrix, this study will try to discover in which part a positive influence BIM have to which problem and the reasons of this positive influence, on the other hand, it may not have a positive influence to all the problems and using the same matrix to create questionnaires as quantities analysis to find out the variance in feedback from individuals who are involved in AEC industry. Then the matrix will be used to administrate interviews with experts in the field where the research is conducted, those experts have a strong solid background in the AEC industry field where BIM is involved in Mega-projects such as "One of the Largest Educational Campuses in the World" *Sabah Al Salem University City*.¹⁵

For the first sight the matrix looks too wide and general, however, it will help to develop an overview about the relationships between each benefit and each problem, and it may lead to discovering new solution for existing problems, but those solutions were not implemented or it can show that some problems will not be solved while using this tools and new technology because the problems are related to human factor and individuals more than the tools itself.

Form now, there is a general vision comes from the literature review that new tools and technologies that were implemented before in AEC industry couldn't deal with the problems created by a human factor which will exist forever, as discussed previously individuals influence can be handled by raising the general awareness of individuals themselves.

¹⁵ <http://ssuc.ku.edu.kw/>

4.2 BIM Benefits – Mega-projects Problems Matrix.

4.2.1 Introduction

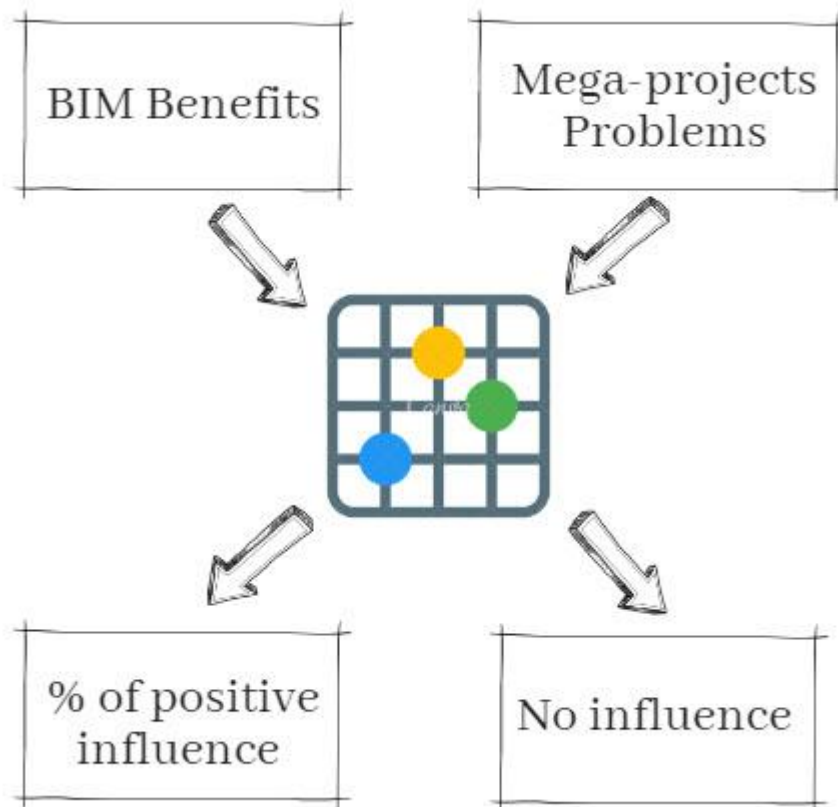


Figure 13 Inputs and Outputs of BIM benefits - Megaprojects problems Matrix¹⁶

BIM Benefits – Mega-projects Problems Matrix will be used to insert the BIM benefits and Mega-projects problems as inputs and by storm minding through the literature review, it will help to figure out which benefits have positive influence to which problems, however in this chapter will not determine any percentage of this positive influence. Those percentages will be determined through the questionnaires and interviews.

In this matrix, the ten most common problems in Mega-projects will be represented on the first row and the benefits of BIM according to each stage in the first and second column. In the colored intersection represents the positive influence that BIM may have according to the first part of the research.

¹⁶ Own figure.

The Mega-projects most common problems were summarized and shorten in the following sequence:

- Complexity of Megaprojects
- Planners change “Project team changes”
- Multi-Stakeholders
- uniqueness bias
- Fail slow
- Rent seeking
- Change in project scope
- High-risk delivery
- budget and time are inadequate
- Misinformation

And the benefits of BIM were classified as follows:

- Benefits to Owner
- Design Benefits
- Construction and Fabrication Benefits
- Post Construction Benefits

The Mega-projects common problems were added in the columns vertically and the BIM benefits were added in the row horizontally and divided into groups according to the project lifecycle and the main stakeholder in each phase. As a result of the literature review, it was found that the positive possible influence of BIM to Mega-projects problems will be in the intersections with the (+) sign.

4.2.2 Owner Benefits “Concept – development design phase”

	BIM Benefits										
Mega-Projects Problems		Complexity of Megaprojects	Planners change	Multi Stakeholders	uniqueness bias	Fail slow	Rent seeking	Change in project scope	High risk delivery	budget and time are inadequate	misinformation
Benefits to Owner	Concept, Feasibility, Design Benefits	+	+	+		+		+		+	+
	Increased Building Performance and Quality	+	+								+
	Improved Collaboration Using Integrated Project Delivery	+	+	+							+

Table 4 BIM Benefits – Mega-projects Problems Matrix. Owner benefits part 1/4.¹⁷

In the concept “development” design phase as the owner is the main stakeholder, of course with the owner “client” it means individuals, organizations, private or public. For this phase, some problems don’t have any influence when using BIM because it will not interfere together like Rent-seeking as the represented of corruption which depends directly on the individuals involved in the process not about the technology or the tools were used. On the other hand, some of this problems were not created yet in the concept design phase as high-risk delivery which can be presented on this stage only if it is a design project and this is not the type of projects meant here. As well for uniqueness bias, it is too early in this stage that the whole project team is thinking about one direction of the project as the influence curve still high and the information curve is low as explained before. Also, some benefits are irrelevant to some problems for example:

- Increased building performance and quality to Multi stakeholders.
- The slow problem, where the whole project team follow one option in the project and miss all other alternatives to the benefits of (Increased Building Performance and Quality - Improved Collaboration Using Integrated

¹⁷ Reference: own tabulation

Project Delivery) as those benefits will not change the fact that the project team is working like a sheep flock in one direction.

- Inadequate budget and time problem, will not be affected by using BIM to Increased Building Performance and Quality, as the project management three main aspects (Time, Budget, Quality) are connected in a triangle, when time and budget go inadequately, there is no place to achieve quality if the project is needed to be accomplished as planned.

4.2.3 Design benefits “Detailed design – construction phase”

	BIM Benefits										
Mega-Projects Problems		Complexity of Megaprojects	Planners change	Multi Stakeholders	uniqueness bias	Fail slow	Rent seeking	Change in project scope	High risk delivery	inadequate budget & time	misinformation
Design Benefits	Earlier and More Accurate Visualizations of a Design	+	+	+	+	+		+		+	+
	Automatic Low-Level Corrections	+				+			+		
	Generation of Accurate and Consistent 2D Drawings	+	+								
	Earlier Collaboration of Multiple Design Disciplines	+	+			+		+	+		
	Easy Verification of Consistency to the Design Intent	+	+	+	+	+		+		+	+
	Extraction of Cost Estimates during the Design Stage	+	+				+	+		+	+
	Improvement of Energy Efficiency and Sustainability	+									

Table 5 BIM Benefits – Mega-projects Problems Matrix. Design benefits part 2/4¹⁸

¹⁸ Reference: own tabulation

In the detailed design stage, the main participants are the owner, architects and other engineers and planners. As mentioned before rent seeking “corruption” will not be affected by using technology, it depends about individuals behavior, yes BIM and BIM clouds are organizing the access and the authority to change the project information, however, at the end, it depends about individuals who have this authority. Even when the project is not feasible or the feasibility studies showing that the project is not profitable on the long run, especially in public sector the hiding hand is still playing a major role to take the decision to start those types of mega-projects. To illustrate the irrelevant relations between some benefits and some other mega-projects problems:

- Planner’s changes or project team changes will not be affected by automatic low-level corrections abilities of BIM tools.
- Planners changes to the improvement of energy efficiency and sustainability, of course, BIM is improving the energy efficiency by offering many analysis options, but in case the project team members are changing through the project life cycle, it will not have an influence to the energy efficiency as the information is available.
- For multi-stakeholders and uniqueness bias, it was affected only by earlier and more accurate visualizations of a design and easy verification of consistency to the design intent, because those two benefits can directly affect the decisions of the stakeholders and can open the project team eyes to alternative scenarios avoiding the uniqueness bias and fail-slow scenarios.
- As well fail-slow will not be affected by the generation of accurate and consistent 2D drawings, as the discovery of alternative scenarios depend more on the 3D visualization and multiple disciplines models coordination.
- The change of project scope is a higher level change which will not be affected by the lowest level benefits as automatic low-level corrections and generation of accurate and consistent 2D drawings.
- The high-risk delivery problem will be affected only by time-saving benefits but not by the quality or accuracy benefits.
- The inadequate time and budget problem meant the initial problem in the development design phase and to take the decision to start a project which is not feasible from the early beginning, and it didn’t mean the inadequate budget and time due to the problems happen during construction.

- Misinformation here meant by the leaking of information and details along the project lifecycle, however it didn't mean the corrections that can happen during the project lifecycle. This illustrating the reason that the automatic low level corrections is not affecting the misinformation problem.

4.2.4 Construction and Fabrication Benefits

	BIM Benefits										
Mega-Projects Problems		Complexity of Megaprojects	Planners change	Multi Stakeholders	uniqueness bias	Fail slow	Rent seeking	Change in project scope	High risk delivery	budget and time are inadequate	misinformatio
Construction and Fabrication Benefits	Use of Design Model as Basis for Fabricated Components	+	+					+	+	+	+
	Quick Reaction to Design Changes	+	+	+		+		+	+	+	+
	Discovery of Design Errors and Omissions before Construction	+	+	+	+	+		+	+	+	+
	Synchronization of Design and Construction Planning	+	+	+		+		+	+	+	+
	Better Implementation of Lean Construction Techniques	+						+			
	Synchronization of Procurement with Design and Construction	+	+	+		+		+	+	+	+

Table 6 BIM Benefits – Mega-projects Problems Matrix. Construction benefits part 3/4¹⁹

¹⁹ Reference: own tabulation

In the construction and manufacturing phase, the main stakeholder influenced by the BIM benefits is the contractor, or any other subcontractors, suppliers, manufacturers, and third parties who are also involved in the project in a lower hierarchy than the general contractor. In this phase, the level of information is increasing rapidly and the level of owner influence is decreasing, which is a good environment for rent seeking “corruption” but those problems are not related to the technology “BIM” as much it is related to individuals behavior. And to illustrate the irrelevant relations between some benefits and some other mega-projects problems:

- Better implementation of Lean construction techniques as one of BIM benefits in construction phase, only had a positive influence on the complexity problem and the change in project scope, the major benefits of lean construction techniques can be noticed in the repetitive models projects such as huge resorts, high rise buildings projects and national residential projects in high population countries, this benefits is significantly useful when testing and collaborating the design and construction of one small unit then implement the optimum plan to the whole project. BIM is allowing the chance to test unlimited design options to select the optimum model to budget, time and quality aspects.
- The multi-stakeholders situation will not be influenced by the usage of the design model as basis on fabrications, because any changes due to stakeholders options will be done within the design model and will be transferred directly manufacturing, so BIM is making a barrier between the design and manufacturing phases, but connecting them in the same time which reduces time and effort.
- Uniqueness bias is only influenced by the discovery of design errors and omissions before construction because it is the only benefit in this stage that can open the project team eyes to alternatives in the project lifecycle, however other benefits will keep the project team thinking about the project as a singular.
- Fail slow scenario is not excepted to be influenced by the usage of design model as a basis for fabricated components, because this scenario comes from the higher level of planning not from the deeper level of details such as components manufacturing.

4.2.5 Post Construction Benefits

	BIM Benefits										
Mega-Projects Problems		Complexity of Megaprojects	Planners change	Multi Stakeholders	uniqueness bias	Fail slow	Rent seeking	Change in project scope	High risk delivery	budget and time are inadequate	misinformation
Post Construction Benefits	Improved Commissioning and Handover of Facility Information	+	+						+		+
	Better Management and Operation of Facilities	+									+
	Integration with Facility Operation and Management Systems	+		+							+

Table 7 BIM Benefits – Mega-projects Problems Matrix. Post Construction benefits part 4/4²⁰

In the post-construction phase and as well for the planning of the existing Mega-projects using BIM, many of the mega-projects common problems are related to the design and construction phases which will already take place in those phases or it is not accepted that it will happen again in future. For example uniqueness bias, fail slow, changing in project scope and inadequate budget and time. All of those common problems are happening during design and construction phases, and when it comes to post-construction phase “what is done is done” and from this perspective, the stakeholders start dealing with the project. Also for high-risk delivery, once the project is delivered and star operation, this problem is not expected as explained before. But of course, in the handing over BIM is extremely need in case it is implemented from the beginning.

BIM models are working like data storages, the more you inputs go inside the more importance it gain with project life cycle, additionally, it is not only a storage, it can coordinate and collaborate between different disciplines and offer alternatives. Nevertheless the coordination between BIM and the systems used in facility management in progress.

²⁰ Reference: own tabulation

5 . Questionnaires and Interviews

5.1 Introduction

This research study the influence of BIM benefits to Mega-projects common problems and to find out if all the benefits have a positive influence on the common problems or some of this problems are irrelevant to BIM. Also, the study is focused on the early phases of the project lifecycle more than in the final phases.

The methodology used for this research approach depends on a detailed literature review, a field survey for the building information management and its influence on Mega-projects. As it is intended to use the questionnaire answers from a group of experienced AEC industry participants and have a good knowledge in the field and followed by statistical analysis of the collected responses to the questionnaire. Then followed by interviews with experts BIM managers who have solid experience in Mega-projects and BIM for more than 10 years. The research will rank the interview results higher than the results of the questionnaires, as the information collected throw the questionnaires represents the mainstream in the AEC industry for BIM, however, the interviews reflect the real impact of BIM benefits to Mega-projects common problems.

5.2 Questionnaires

5.2.1 Questionnaire Design

It has been selected to make a questionnaire on the research point to get a clear vision about the influence of building information management to Mega-projects common problems. But in the same time, those Mega-projects problems still happening in other projects as well, even if not all the answers were done by participants who have been working in mega-projects, but their answers represent the influence of BIM to the AEC industry in general. The questionnaires were divided into:

- Introduction to explain that the information collected is for academic purposes and explaining some terms such as (Uniqueness bias, Fail-slow, Rent-seeking).
- Organizational question, and in this part the target was to identify, the participant background and experience, also the organization and the nature of the projects

involved. The last question in this part and according to the position of the participant (Owner , Consultant, Contractor, facility manager) to redirect the participant to the group of questions related to the background and the experience, because it is expected that the participants of owner and consultant background will overestimate the benefits of building information management and the participants form contactor background will underestimate the benefits of building information management, as the mainstream of those positions to exclude any unnecessary or non-essential requirement to reduce the cost even if this thing may be beneficial in future.

- Owners part to collect data from individuals who have been working in the development design stages and the pre-construction stages. The questions structure was built according to the BIM benefits – Mega-projects problems Matrix.
- Designers or planners “Architects and Engineers” part to collect data from individuals who have been working in the detailed design stages, the pre-construction stages and have been involved in the construction stage itself. The questions structure was built according to the BIM benefits-Mega-projects problems Matrix.
- Construction and manufacturing part to collect data from individuals who have been working in the construction and manufacturing stage. The construction stage itself is a manufacturing process take place in the construction site, but what is meant here by manufacturing is the process of manufacturing components outside site then it will be installed on site. The questions structure was built according to the BIM benefits – Mega-projects problems Matrix.
- Post construction part to collect data from individuals who have been working in the post-construction stages such as commissioning and handing over, facility management and BIM for existing buildings. The questions structure was built according to the BIM benefits – Mega-projects problems Matrix.
- The questionnaire designed to be answered with a gradual degree for answers as follow:
 - Strongly agree (100%)
 - Agree (75%)

- Neutral (50%)
- Disagree (25%)
- Strongly disagree (0%)

5.2.2 Methods of Distribution of Questionnaire

The questionnaire designed to collect feedback and opinions for random answers from individuals with experience with BIM and/or Mega-projects so it has been distributed by more than one way to achieve the principle of random but within the target group.

Different ways used to distribute the questionnaire:

- Delivered to BIM experts through BIMarabia “*the first (Arabic) e-magazine specialized in Building Information Modeling*” and most of the members have a solid experience in Mega-projects in the Middle East region.²¹
- Delivered for previous companies and group work where the author had been working before through internet.
- The questionnaire has been created in survey website to be much easier to be distributed to more different individuals.²²
- The link put in public media like groups for BIM experts at different pages to collect random responses.
- It has been distributed to the sites that include large groups of engineers.

5.2.3 Analysis of Questionnaire Results

- **General**

A number of researches have been done to find out the influence of BIM benefits to Mega-projects common problems by conducted questionnaire is done to investigate the point of view of most of the companies participating in that field according to their BIM – Mega-projects knowledge and experience. This part also contains an analysis

²¹ <http://bimarabia.com/>

²² <https://www.google.com/forms/about/>

of the collected data about participants (general information for years of experience and their company fields like contractor or consultant) which will help in understanding the characteristics of the selected sample for the questionnaire. The questionnaires were built according to the BIM Benefits – Mega-projects Problems Matrix explained before in Chapter 4.

- **Analysis of Questionnaire General Information**

The total responses of the questionnaires are 33 responds, the data was refined because of some spelling mistakes and using other languages than English, also to exclude a test was done to check the form before it was published, so the real number of response is 32, not 33.

5.2.3.1 Organization Questions Analysis.

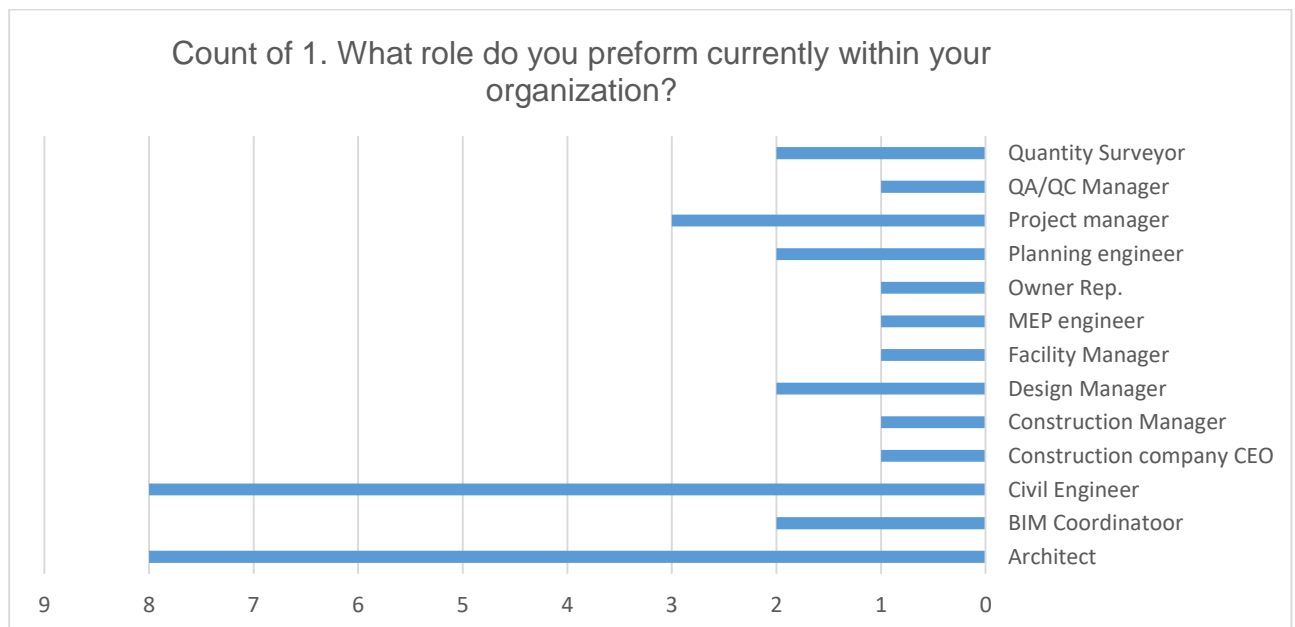


Figure 14 Chart showing the role of the participants within their organization.

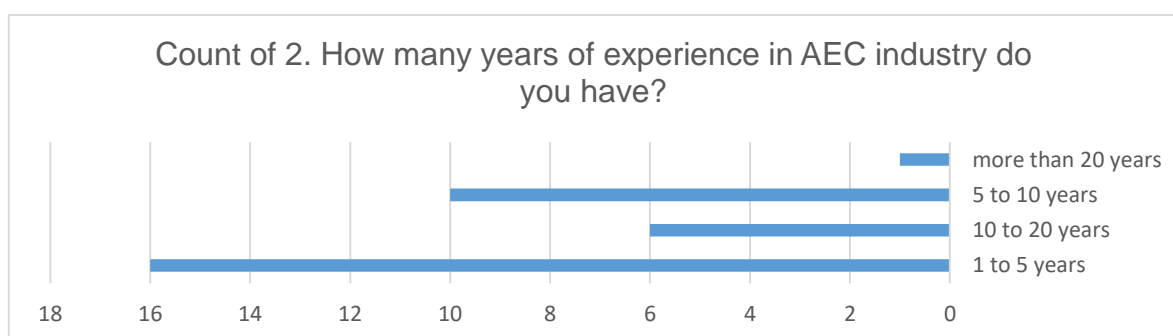


Figure 15 Chart showing the participant's years of experience in AEC industry

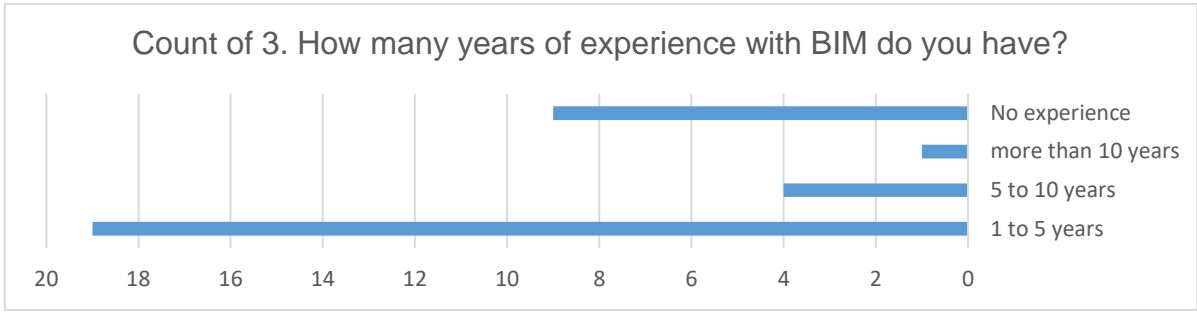


Figure 16 Chart showing the participant's years of experience in BIM

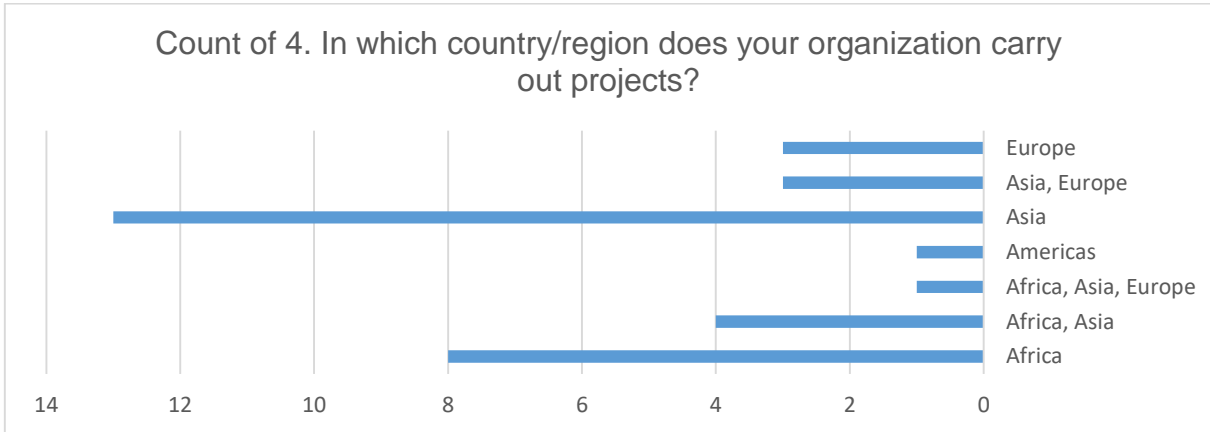


Figure 17 Chart showing the participant's organization projects region

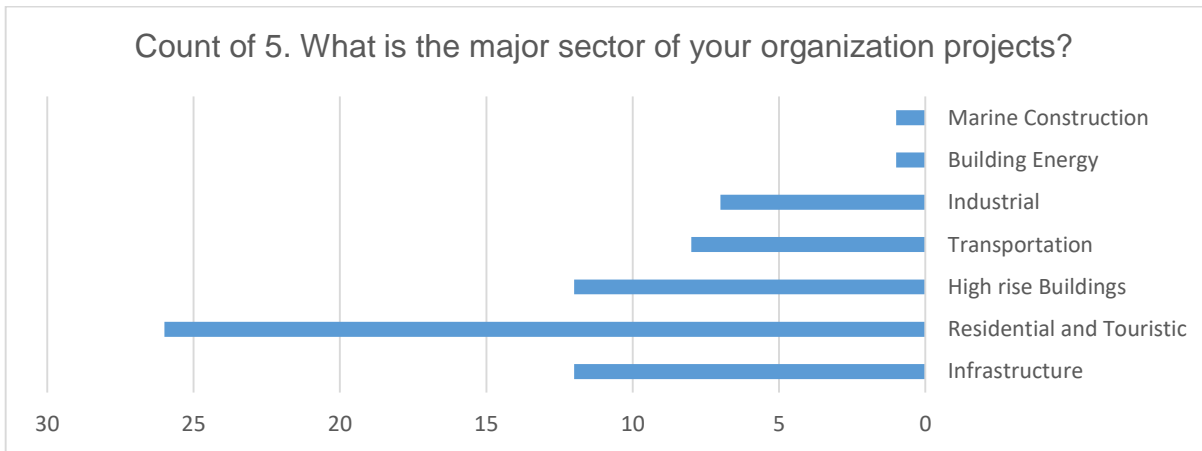


Figure 18 Chart showing the participant's organization projects sector

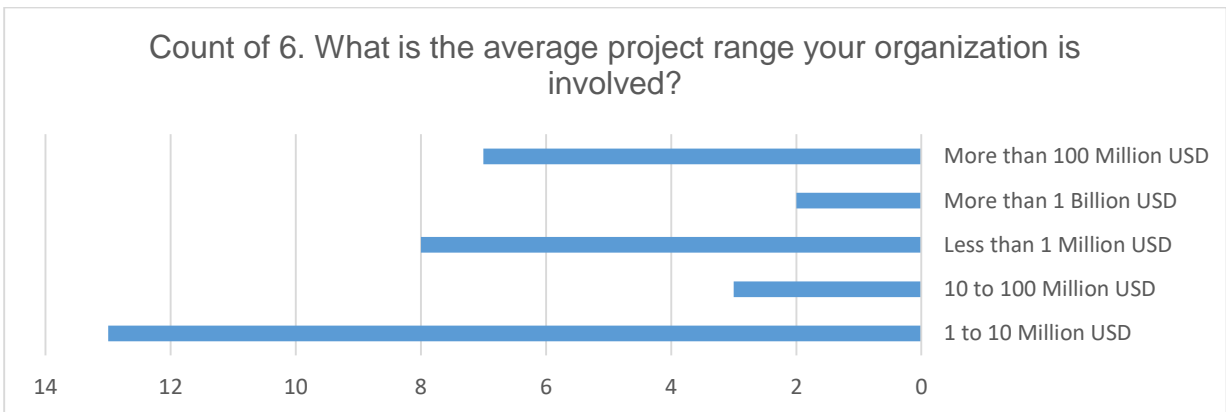


Figure 19 Chart showing the participant's organization projects range



Figure 20 Chart showing the participant's organization usage of BIM

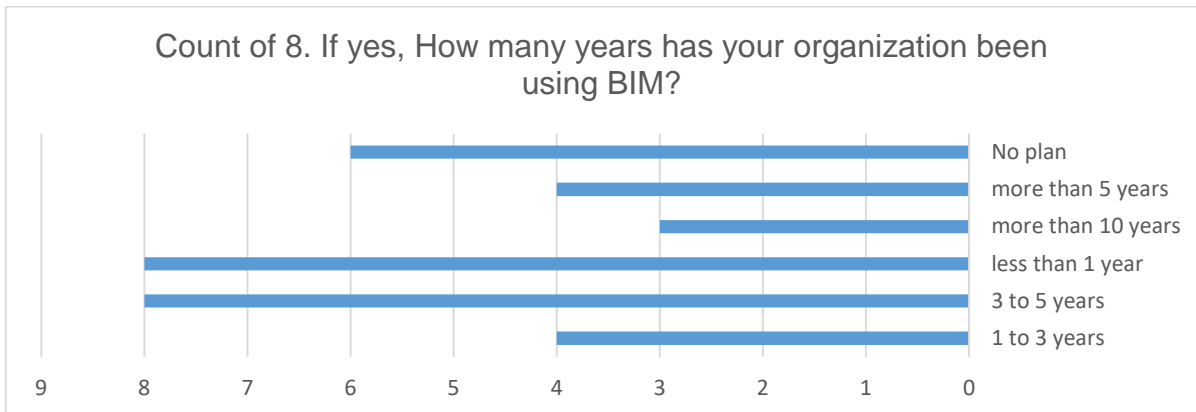


Figure 21 Chart showing the participant's organization period of using BIM

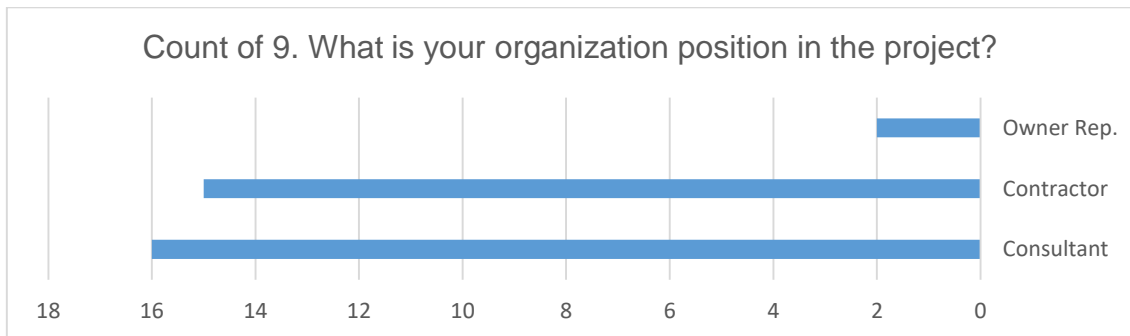


Figure 22 Chart showing the participant's current role within his organization

• Conclusion of Organizational questions

To conclude and evaluate the participants in the questionnaires, by observation of the organization questions results the following note were found:

- More than 50% of the participants have more than 5 years' experience in AEC industry.
- More than 70% of the participants have at least one year of experience in BIM.
- More than 60% of the Mega-projects are in Asia, considering China and Arab gulf oil countries, it would be a logic result.

- More than 50% of the projects are High rise buildings and Infrastructure which is the problematic Mega-projects discussed before.
- 35% of the projects are more than 10 million USD, but according to the general definition of Mega-project it is not only about budget, it is also about the level of stakeholders and local society interest in the project.
- More than 60% of the organizations are using BIM, but it doesn't reflect the participant knowledge. And 50% of the organizations have a plan to implement BIM in the next 5 years.
- More than 60% of the organizations have been using BIM for at least 1 year.
- Almost half of the participants are working in the role of consultant and the other half working in the role of contractor, it will be a reason to exclude the results of the development and post construction phases.

5.2.3.2 Owner 'Development phase' Questions Analysis.

How far do you agree with the following statements?

Only one participant and all the answers were strongly agree. In this part in the final matrix results, the questionnaires results will not be considered because of the low number of participants. The results from the interviews only will be considered.

5.2.3.3 Designers 'Pre-construction & construction phases' Questions Analysis.

How far do you agree with the following statements?

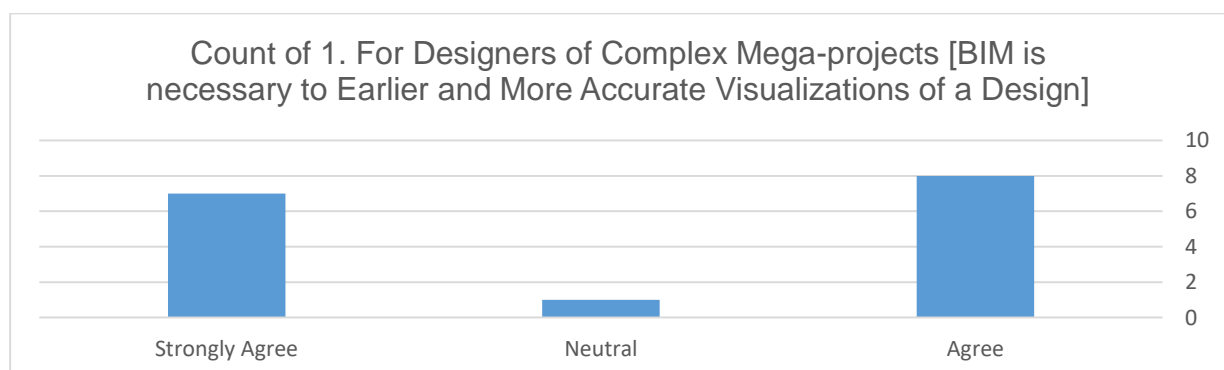


Figure 23 Designers Questions part 1-1

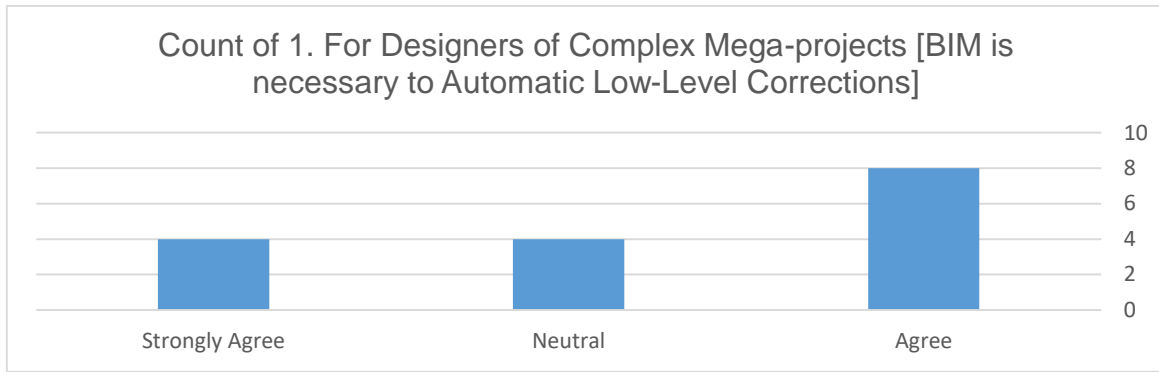


Figure 24 Designers Questions part 1-2

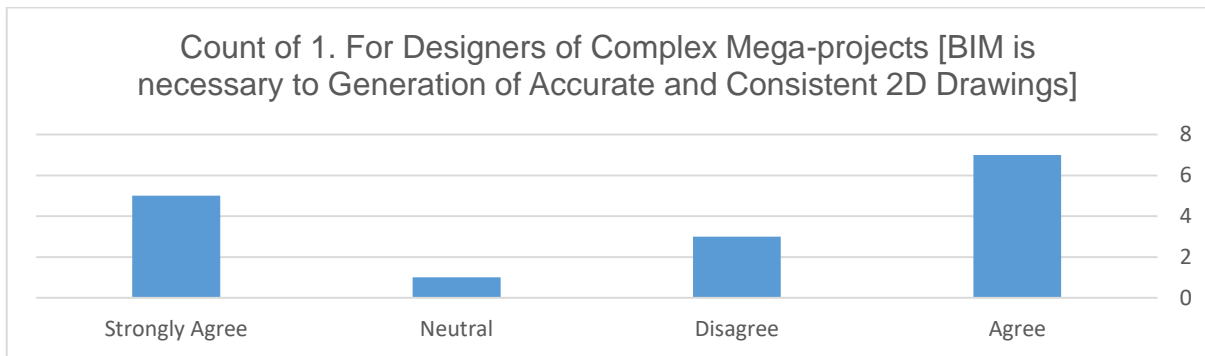


Figure 25 Designers Questions part 1-3

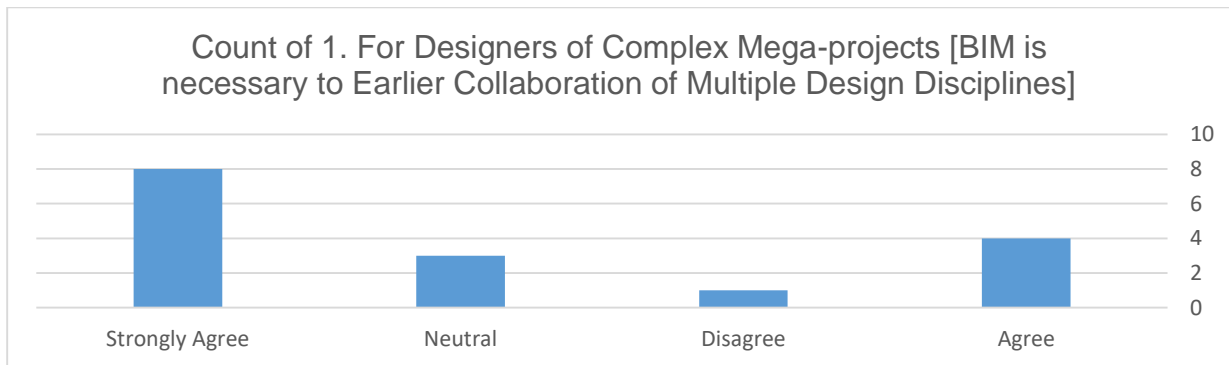


Figure 26 Designers Questions part 1-4

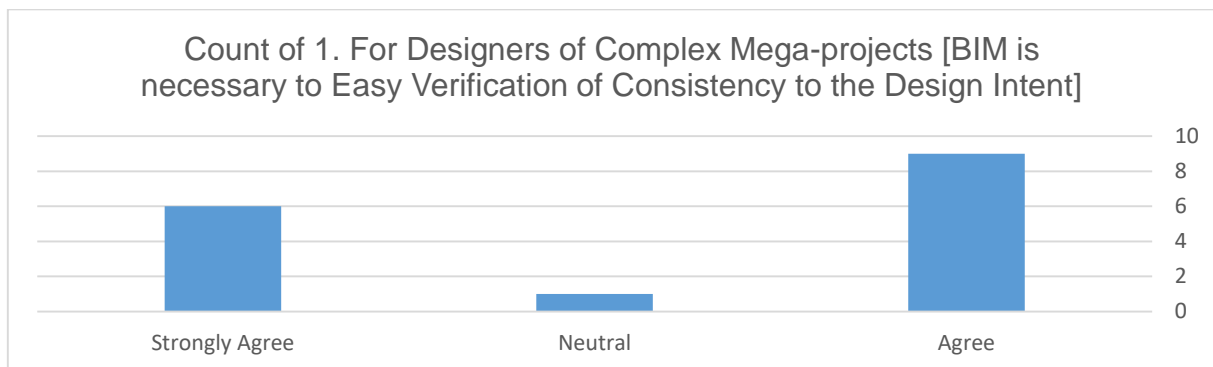


Figure 27 Designers Questions part 1-5

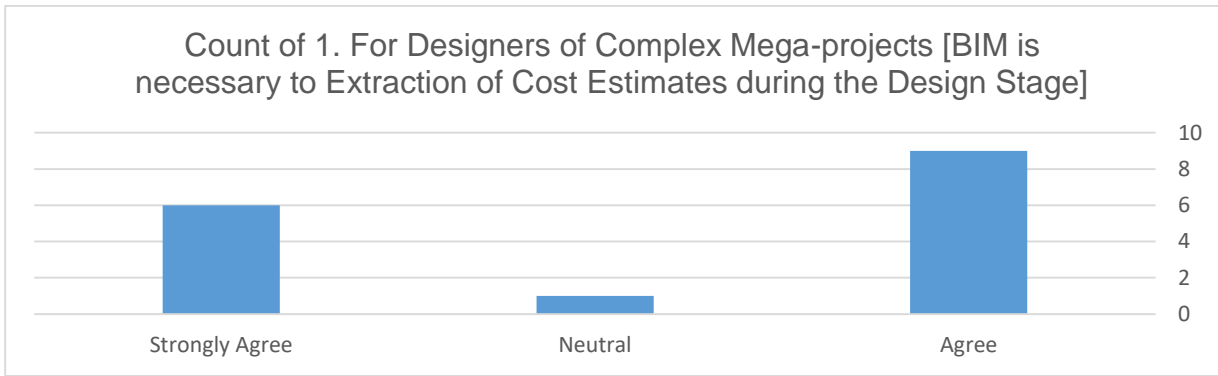


Figure 28 Designers Questions part 1-6

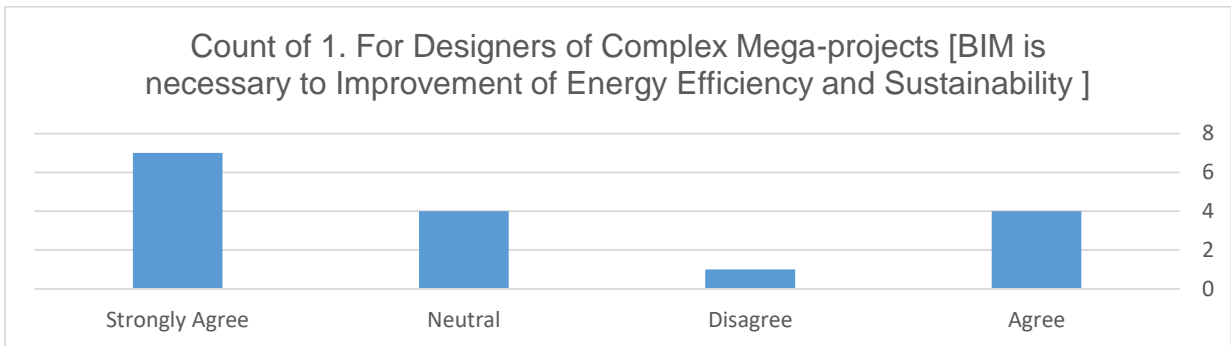


Figure 29 Designers Questions part 1-7

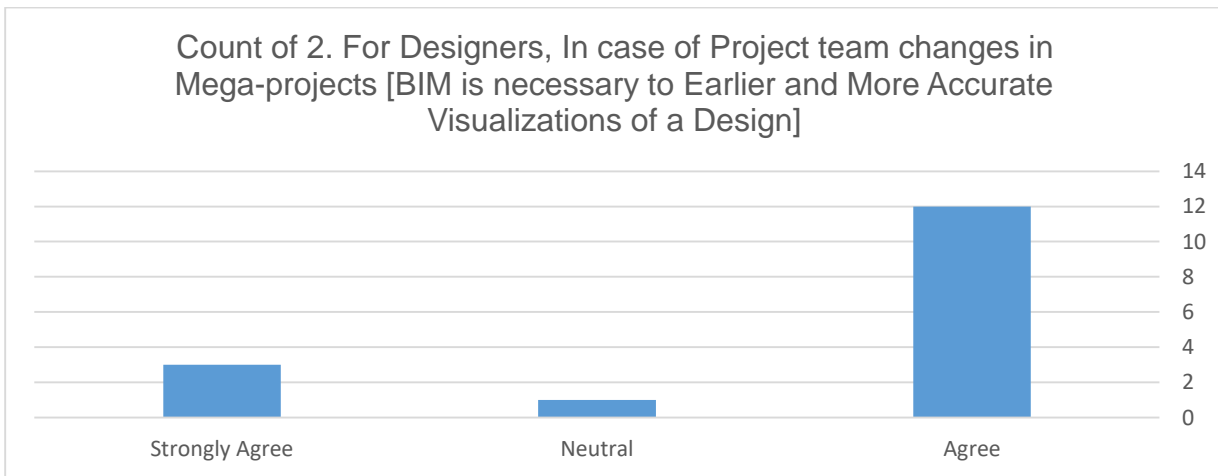


Figure 30 Designers Questions part 2-1

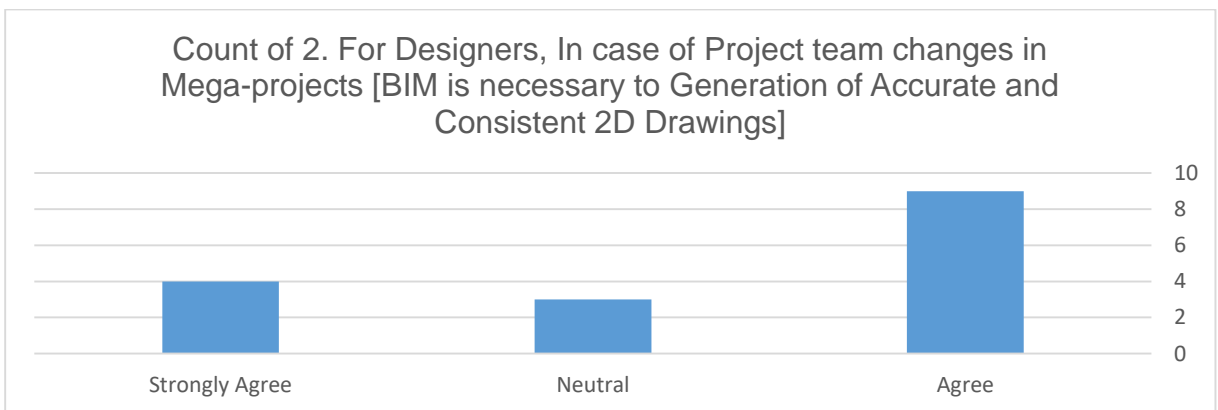


Figure 31 Designers Questions part 2-2

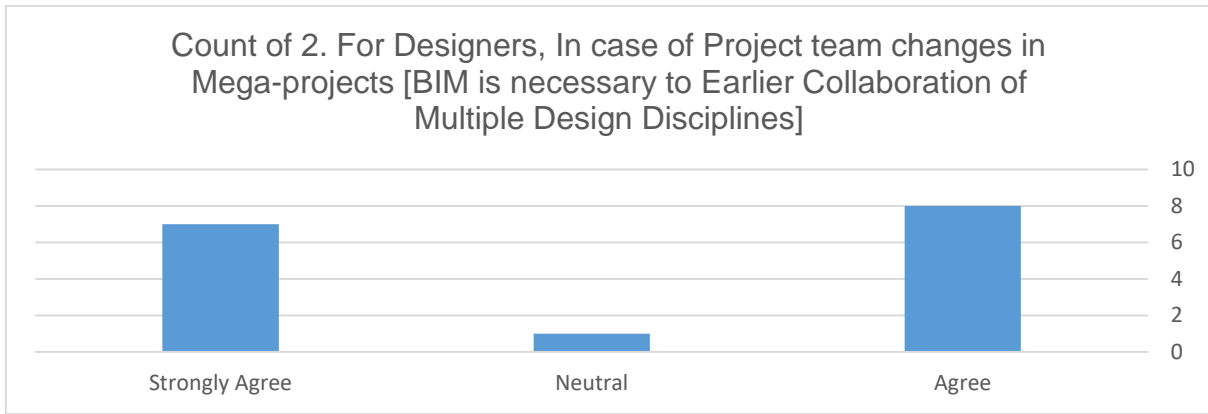


Figure 32 Designers Questions part 2-3

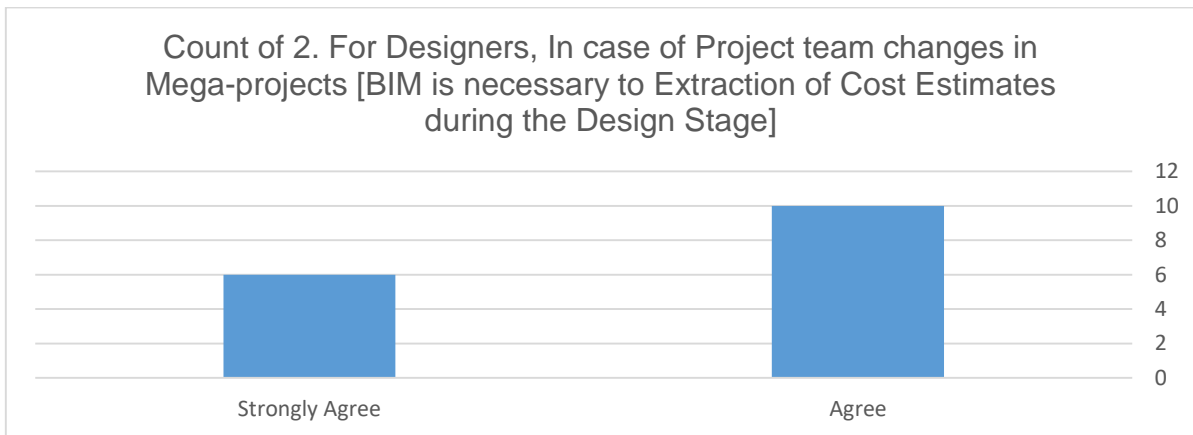


Figure 33 Designers Questions part 2-4

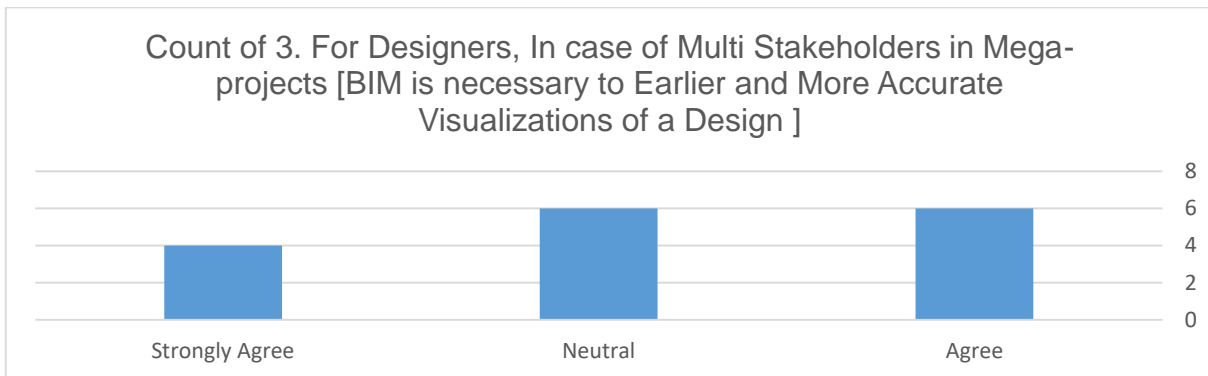


Figure 34 Designers Questions part 2-5

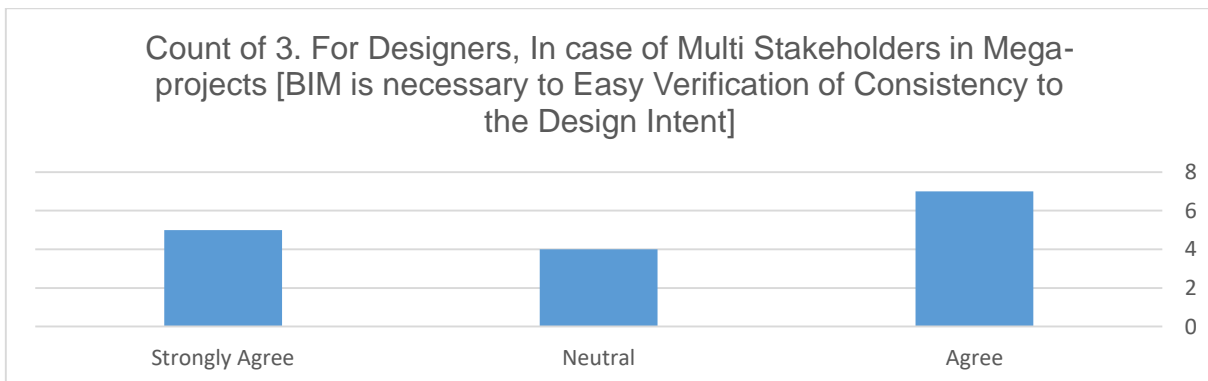


Figure 35 Designers Questions part 3-1

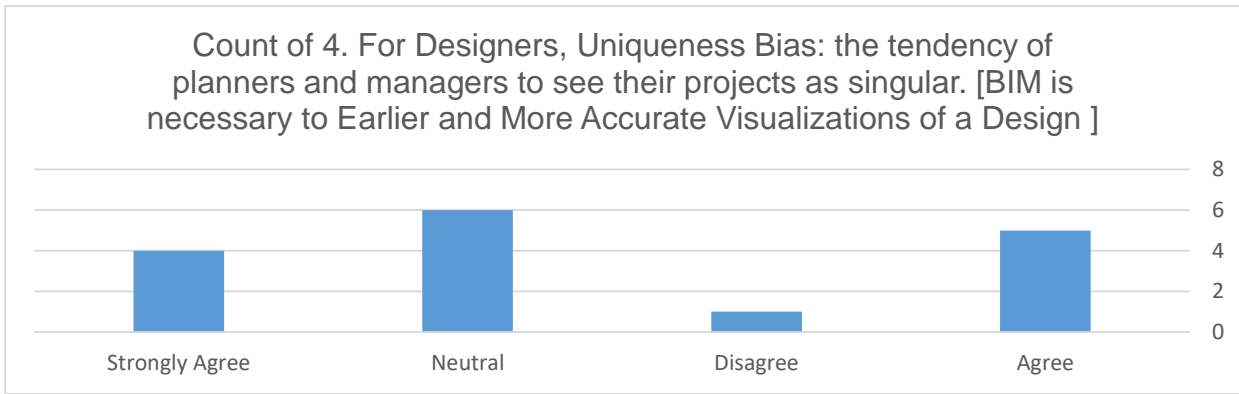


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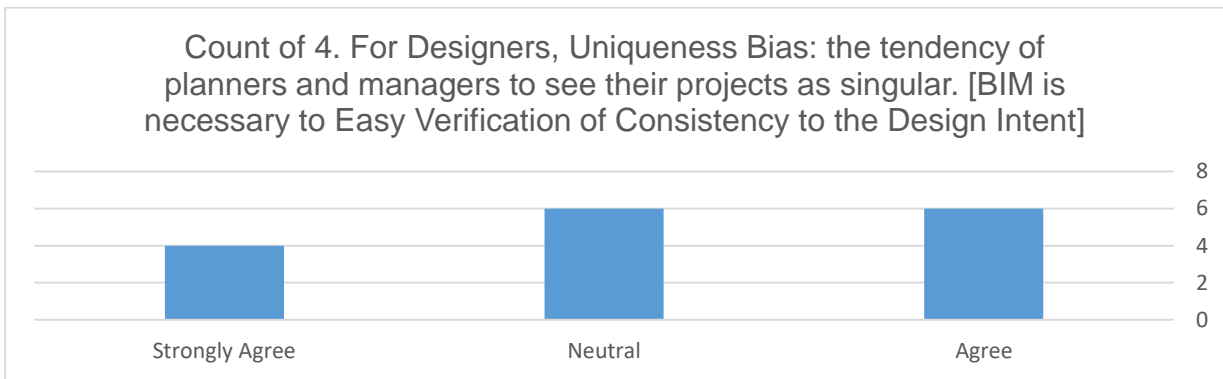


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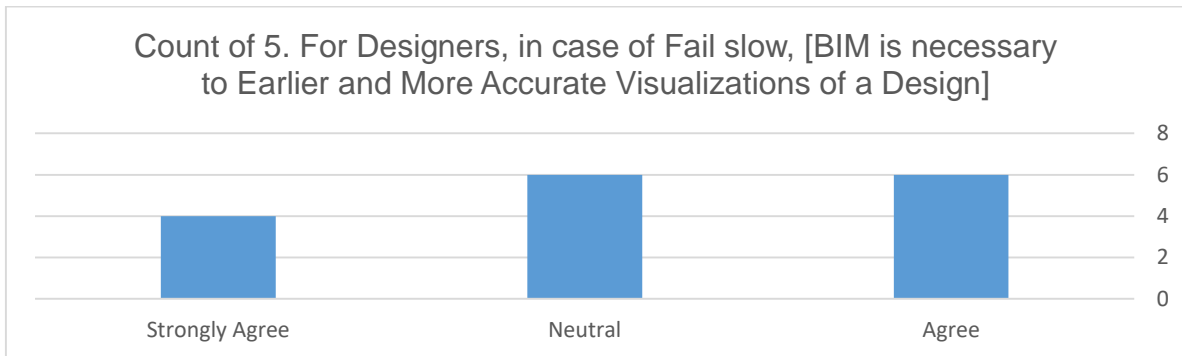


Figure 38 Designers Questions part 5-1

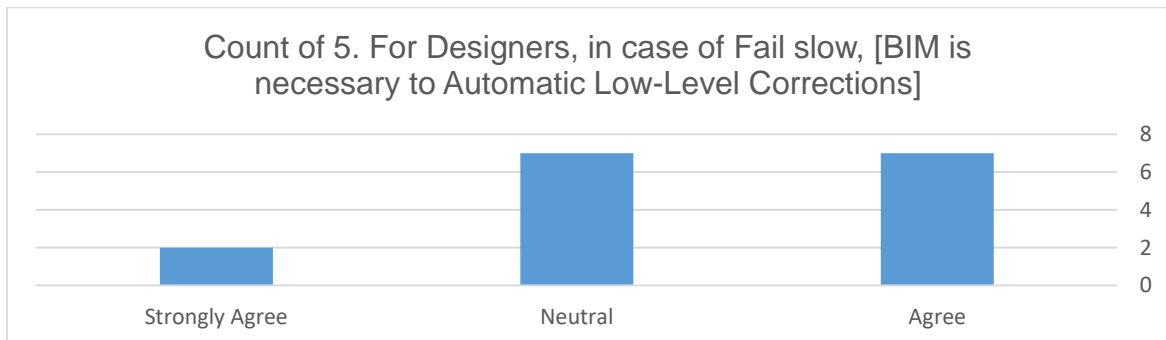


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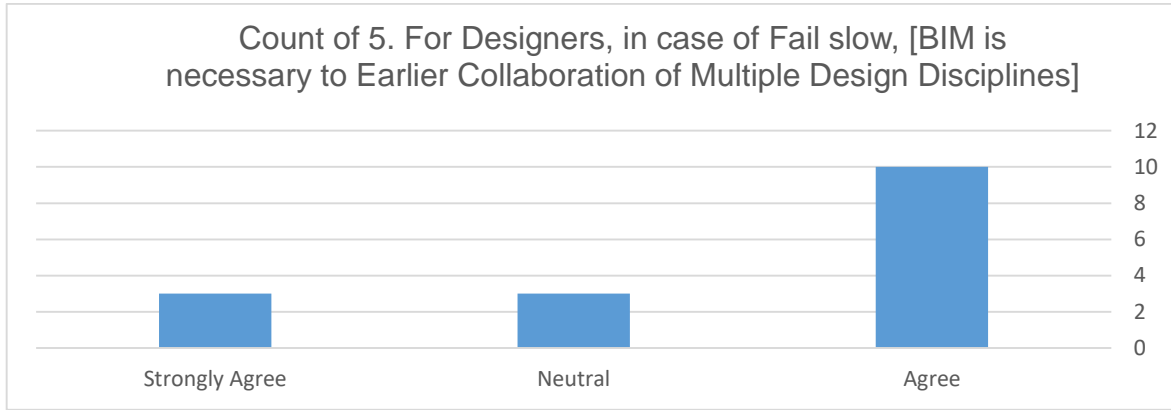


Figure 40 Designers Questions part 5-3

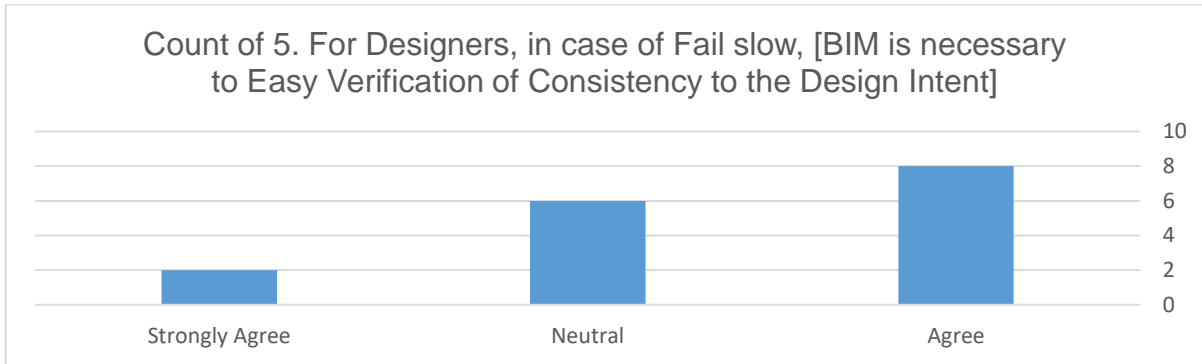


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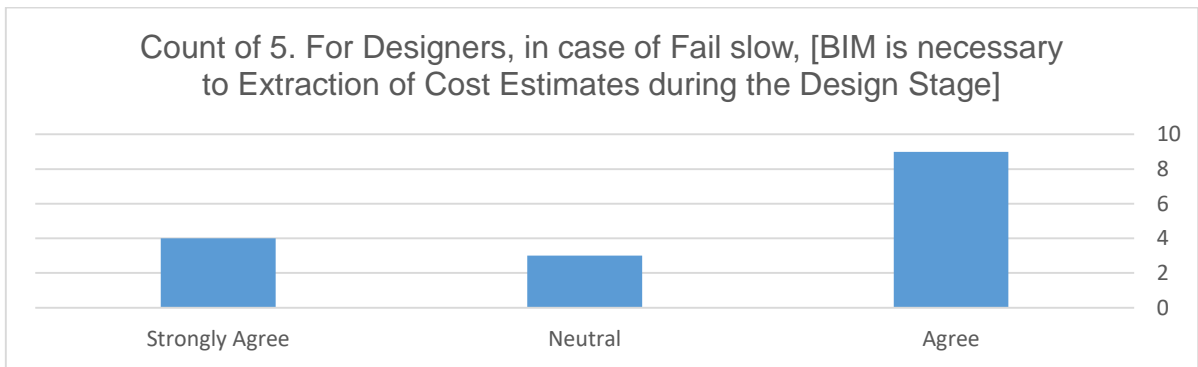


Figure 42 Designers Questions part 5-5

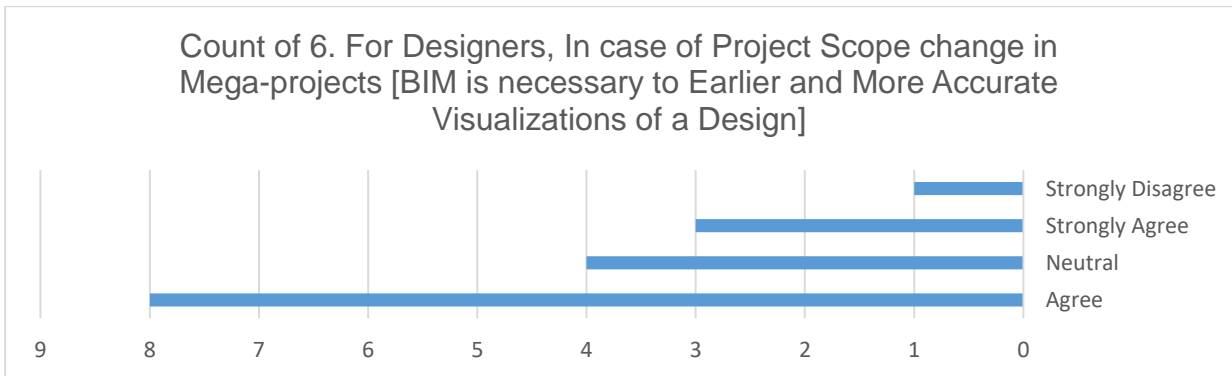


Figure 43 Designers Questions part 6-1

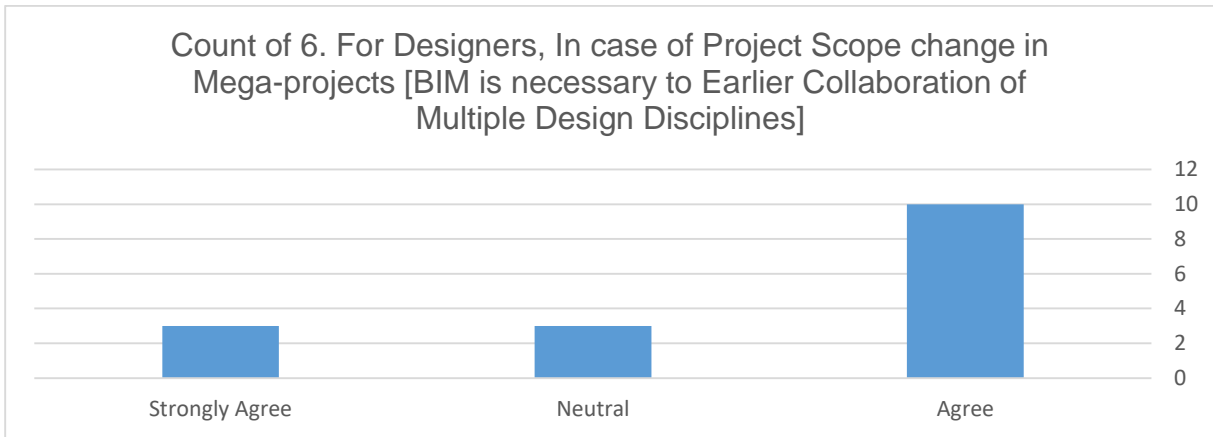


Figure 44 Designers Questions part 6-2

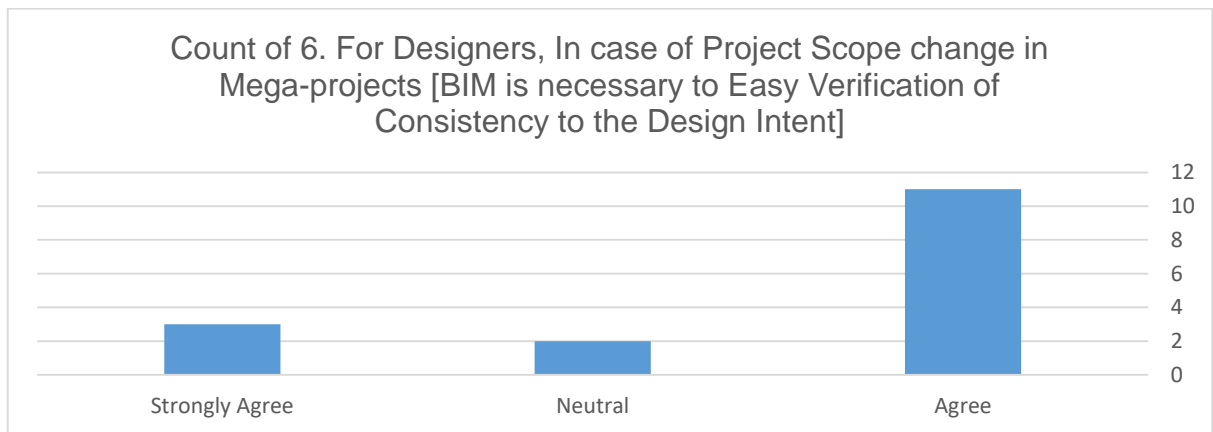


Figure 45 Designers Questions part 6-3

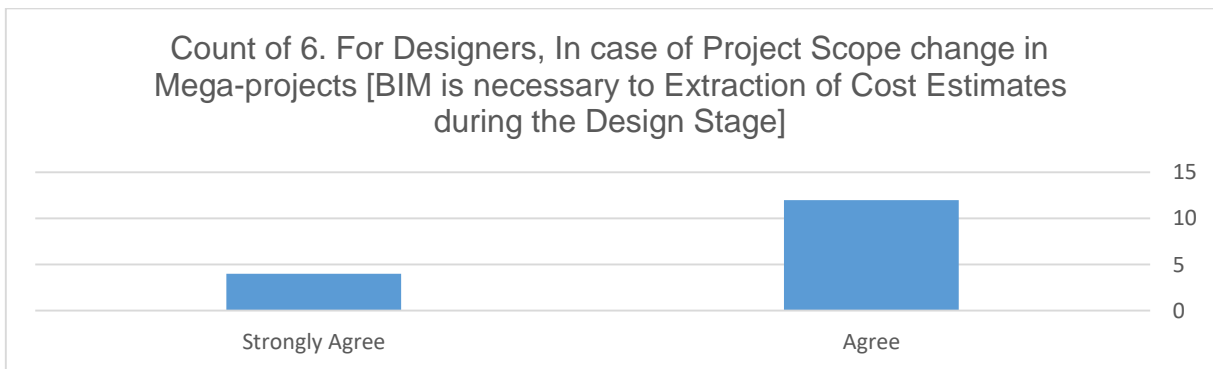


Figure 46 Designers Questions part 6-4

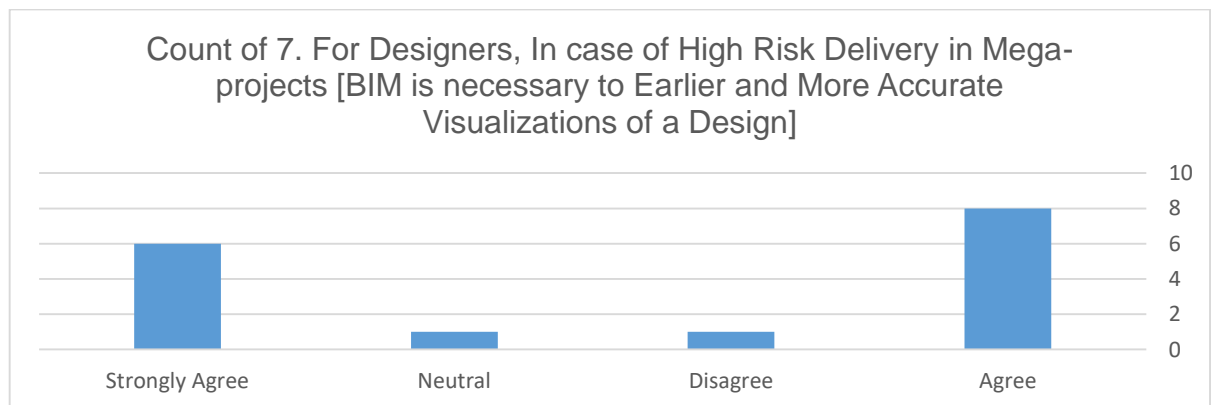


Figure 47 Designers Questions part 7-1

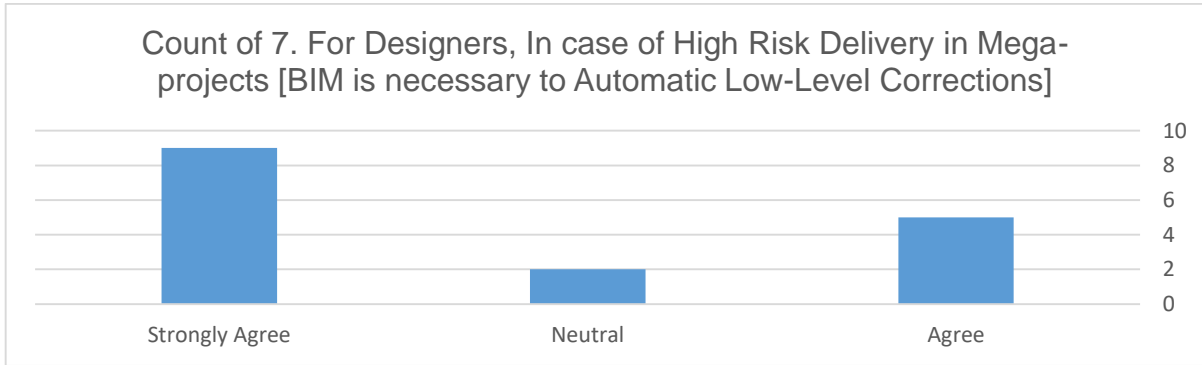


Figure 48 Designers Questions part 7-2

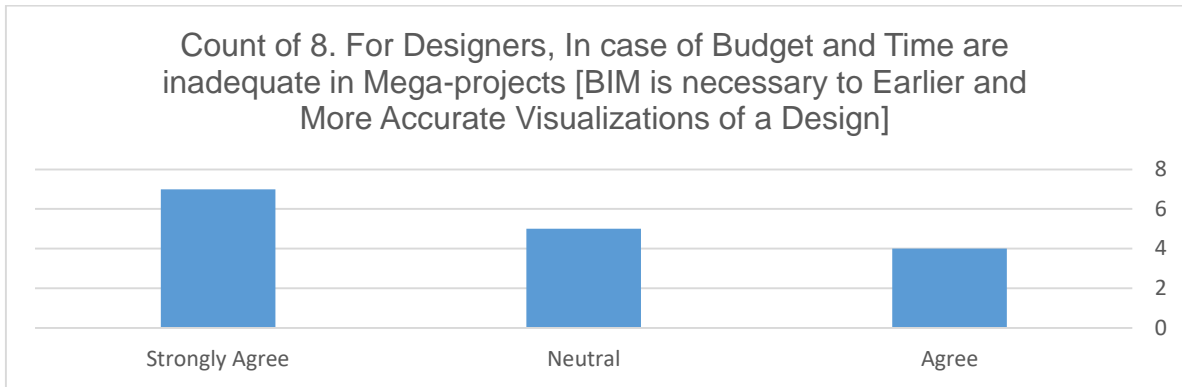


Figure 49 Designers Questions part 8-1

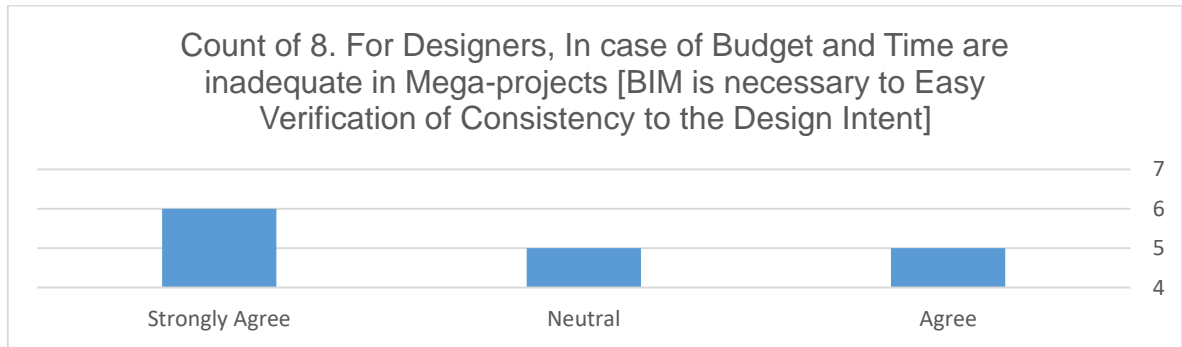


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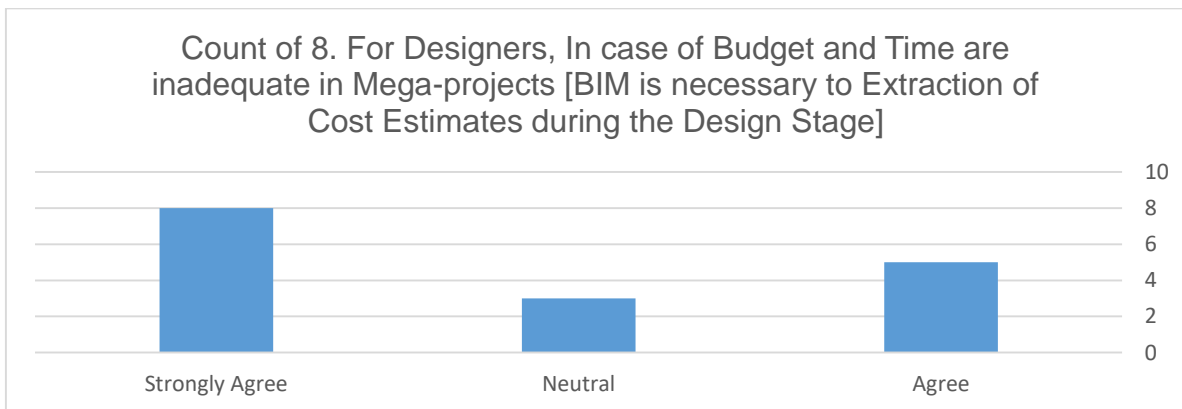


Figure 51 Designers Questions part 8-3

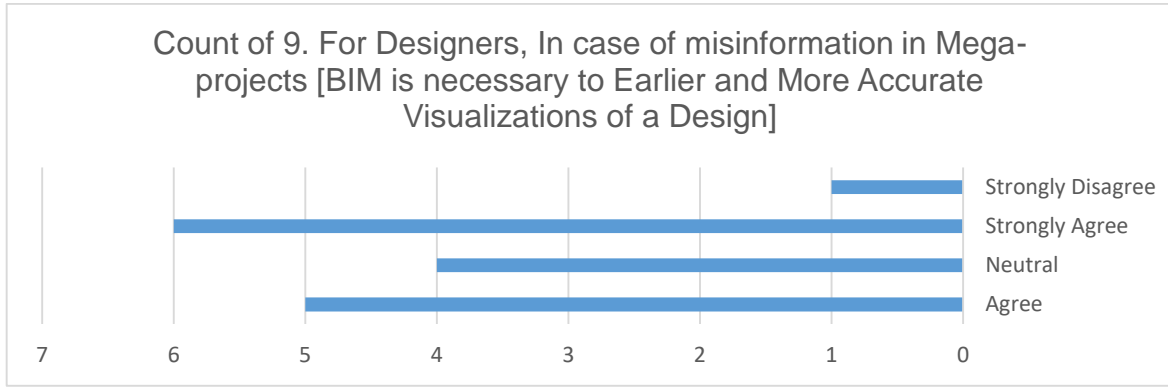


Figure 52 Designers Questions part 9-1

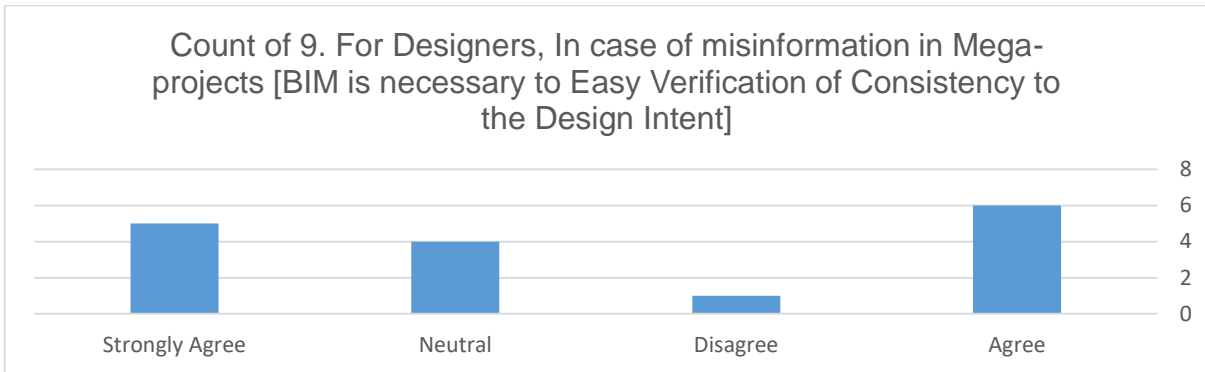


Figure 53 Designers Questions part 9-2

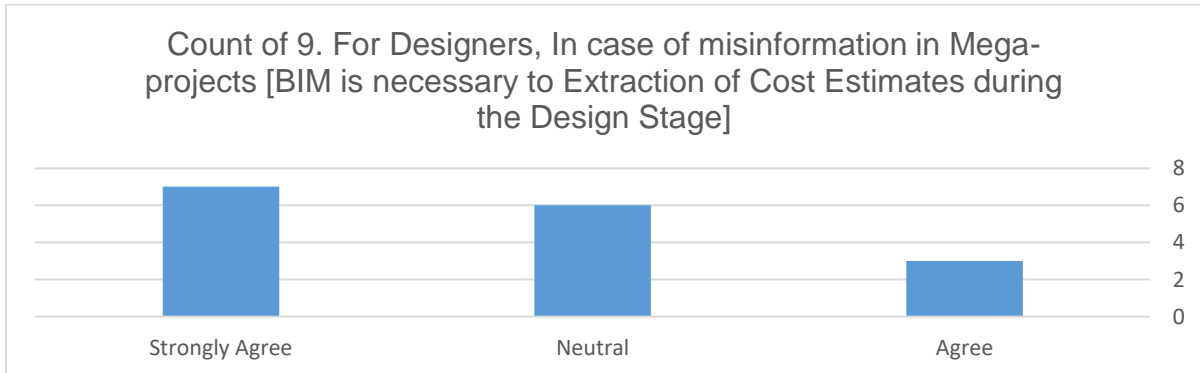


Figure 54 Designers Questions part 9-3

- **Conclusion of designers 'Pre-construction & construction phases' Questions Analysis**

	BIM Benefits												
Mega-Projects Problems		Complexity of Megaprojects	Planners change	Multi Stakeholders	uniqueness bias	Fail slow	Rent seeking	Change in project scope	High risk delivery	inadequate budget & time	misinformation	Average	
Design Benefits	Earlier and More Accurate Visualizations of a Design	84%	78%	72%	69%	72%		69%		78%	73%	74%	
	Automatic Low-Level Corrections	75%				67%			80%			74%	
	Generation of Accurate and Consistent 2D Drawings	72%	77%									75%	
	Earlier Collaboration of Multiple Design Disciplines	80%	84%			75%		75%	86%			80%	
	Easy Verification of Consistency to the Design Intent	83%		77%	72%	69%		77%		77%	73%	75%	
	Extraction of Cost Estimates during the Design Stage	83%	84%				77%		81%		83%	77%	81%
	Improvement of Energy Efficiency and Sustainability	77%											77%
Average	79%	81%	75%	71%	72%			75%	83%	79%	74%	77%	

Table 8 Conclusion of designers 'Pre-construction & construction phases' Questions Analysis²³

According to the analysis of questionnaires results for the BIM benefits influence to the Mega-projects common problems in the design phase, the following findings were observed:

²³ Reference: own tabulation

- With 67% the lowest percentage, the influence of Automatic Low-Level Corrections to fail slow scenarios, explaining that using a tool or a technology to make auto-corrections throw the design phase will not have much effect to the designers' design concept which may lead the project to fail slow scenario.
- Earlier and More Accurate Visualizations of a Design, Extraction of Cost Estimates during the Design Stage and Earlier collaboration of multiple design disciplines got 84% positive influence when it comes to the complex nature of mega-projects and the workflow gap that can happen in case there is a change in the project team members.
- The earlier collaboration of multiple design disciplines (80% average positive influence) and Extraction of cost estimates during the design Stage (81% average positive influence) were the highest design benefits of BIM that can have positive influence to the Mega-projects common problems.
- The following four mega-projects common problems got the highest influence percentage from BIM design benefits:
 - Complexity of Megaprojects. (79%)
 - Planners change "Project team change" (81%)
 - High-risk delivery. (83%)
 - Inadequate budget & time (79%)

Which gives an optimistic vision to implement BIM in the design phase to deal with the mega-projects common problems.

- The cells in the table without percentages represent that no influence of a certain BIM benefits were found related to this certain problem and those findings were found previously from the literature review.
- Overall positive influence of the whole BIM benefits in the design phase to the most common problems of Mega-projects was found to be 77%, this percent is addressing the importance of implementing BIM in Mega-projects design phase regardless the cost of implementing because it is not comparable to the budget of the project at any aspect.

5.2.3.4 Contractors & Manufacturers ‘construction phases’ Questions Analysis.

How far do you agree with the following statements?

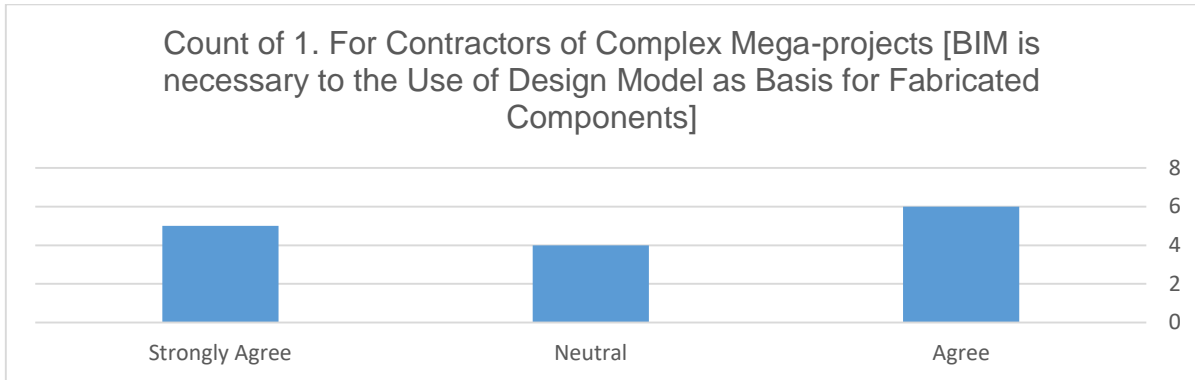


Figure 55 Contractors Questions part 1-1

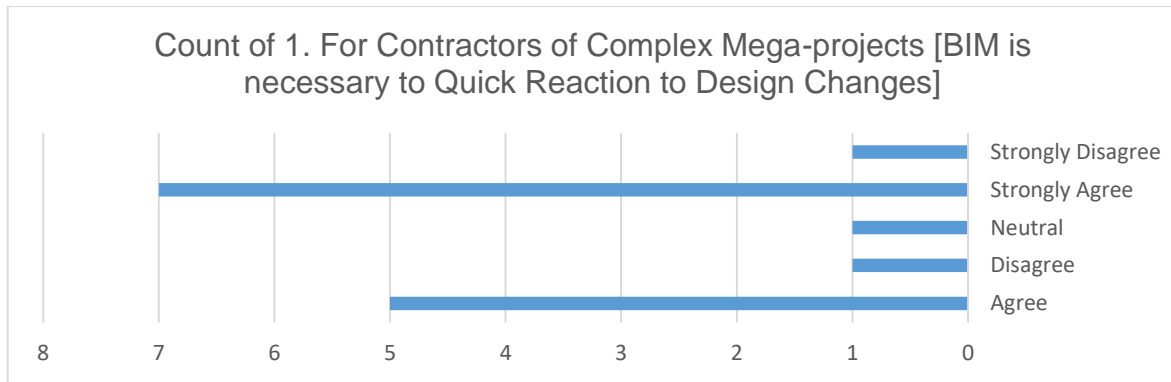


Figure 56 Contractors Questions part 1-2

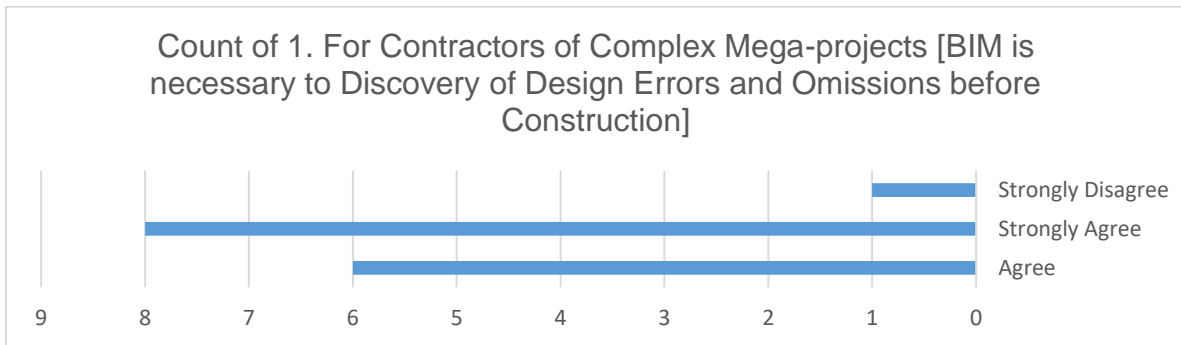


Figure 57 Contractors Questions part 1-3

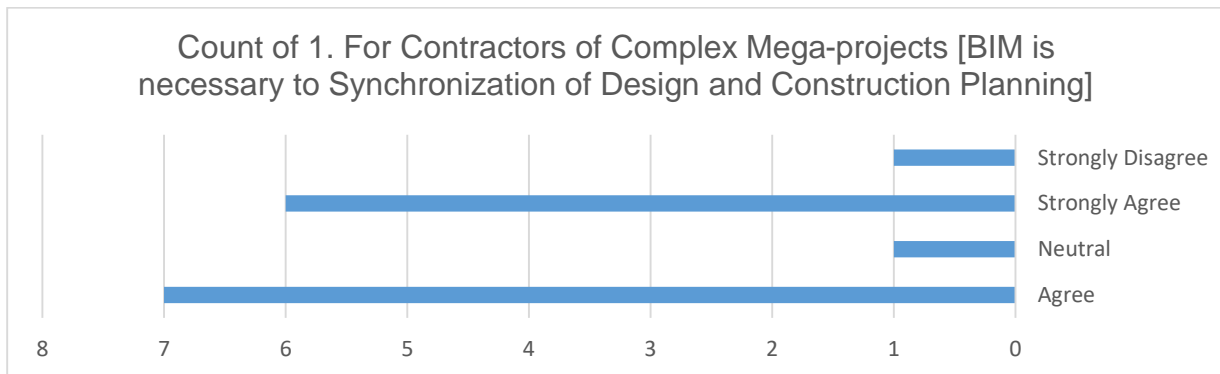


Figure 58 Contractors Questions part 1-4

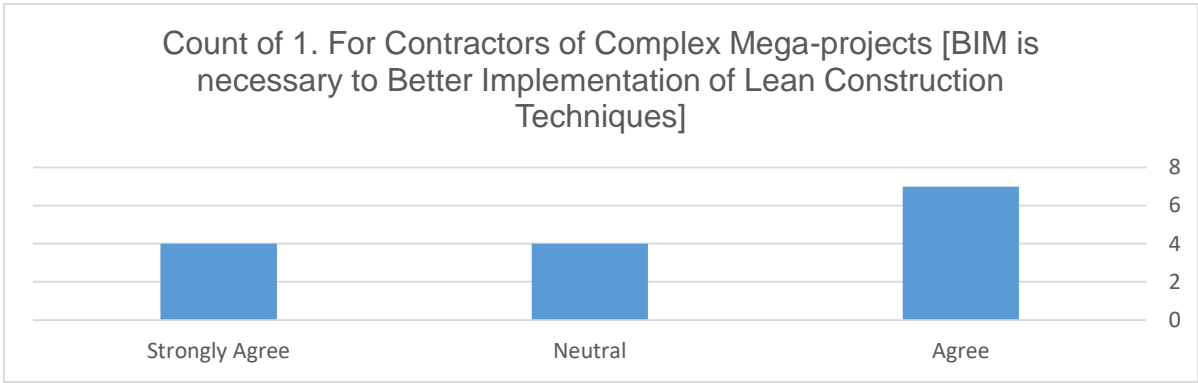


Figure 59 Contractors Questions part 1-5

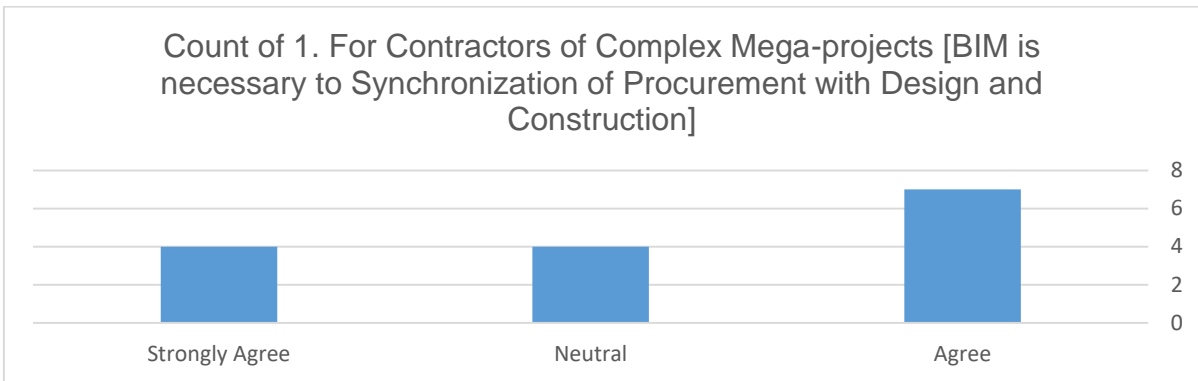


Figure 60 Contractors Questions part 1-6

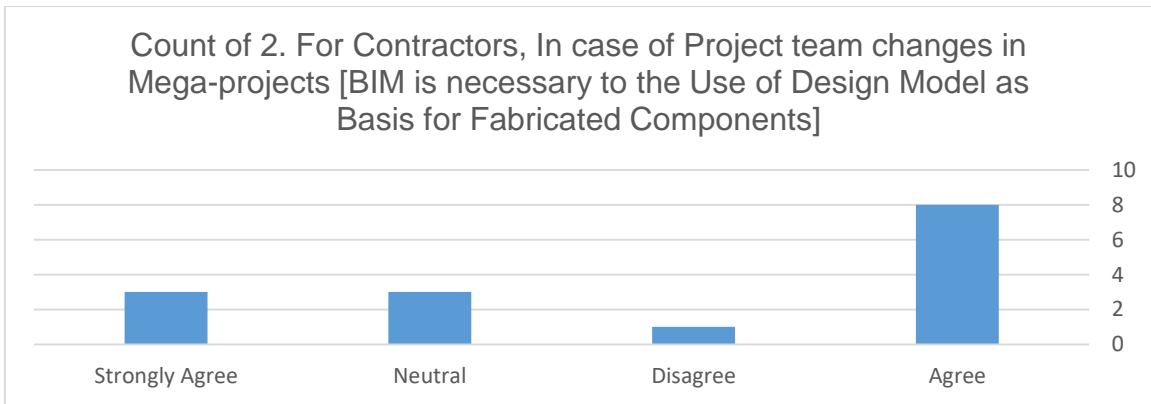


Figure 61 Contractors Questions part 2-1

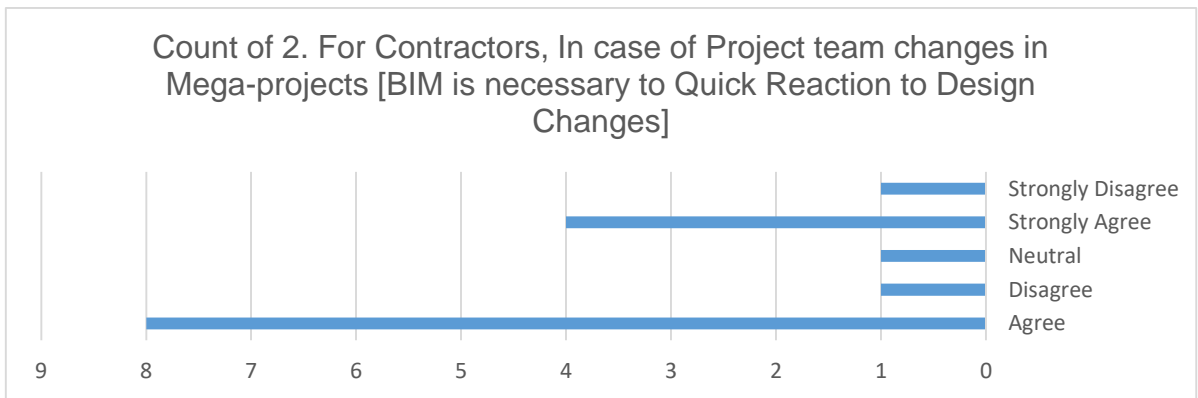


Figure 62 Contractors Questions part 2-2

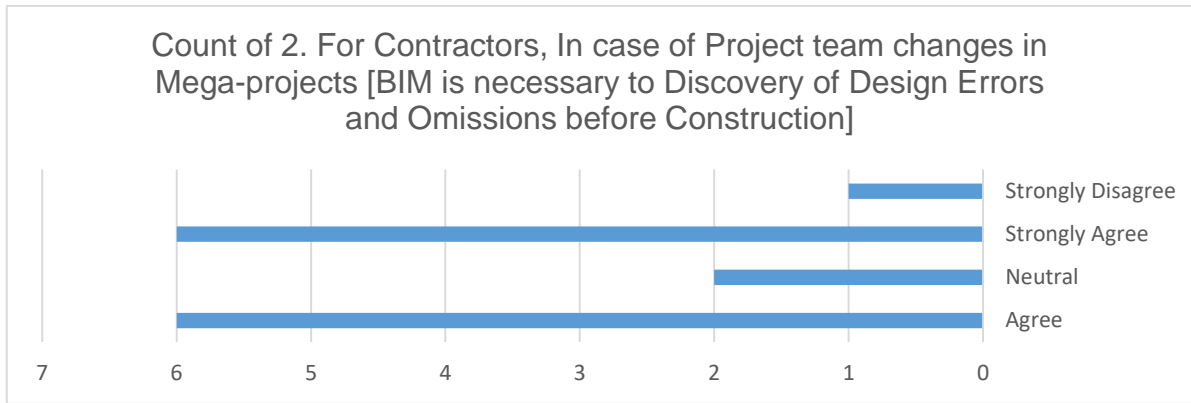


Figure 63 Contractors Questions part 2-3

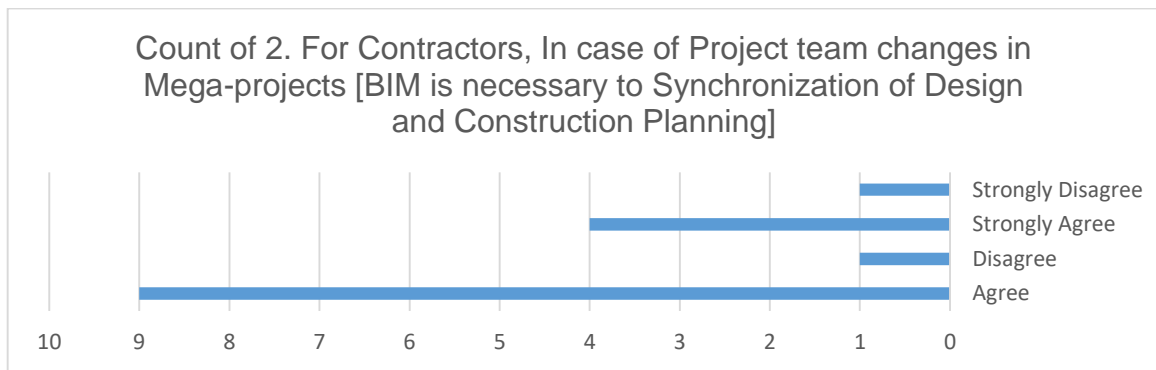


Figure 64 Contractors Questions part 2-4

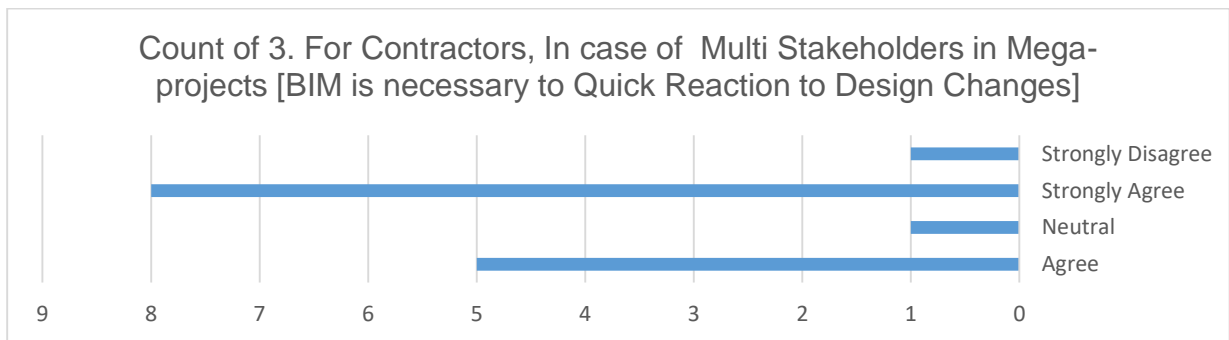


Figure 65 Contractors Questions part 3-1

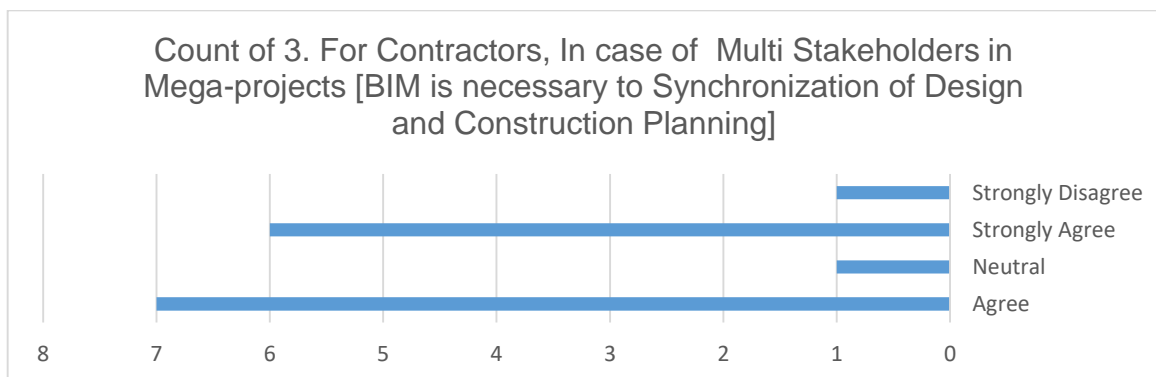


Figure 66 Contractors Questions part 3-2

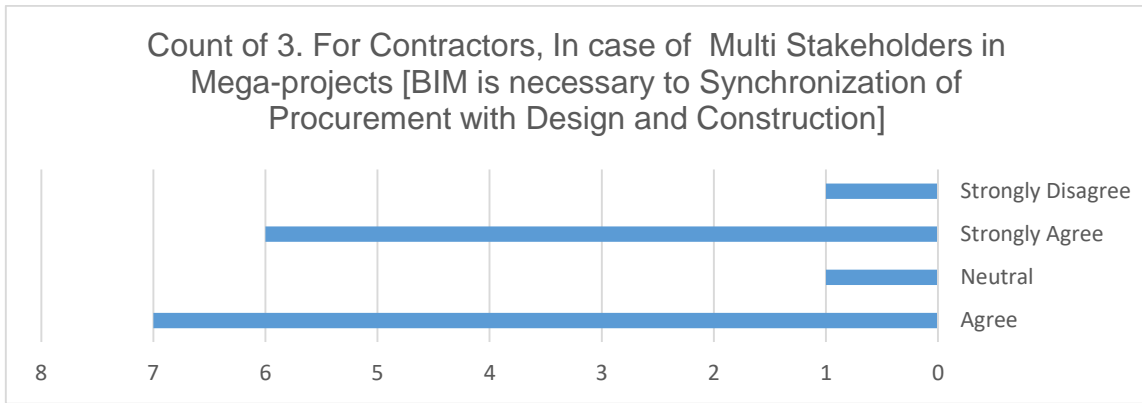


Figure 67 Contractors Questions part 3-3

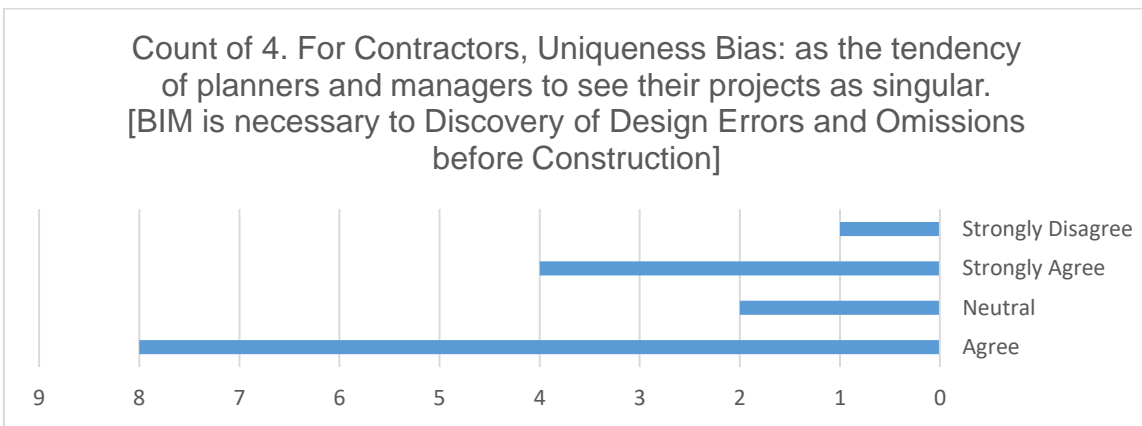


Figure 68 Contractors Questions part 4-1

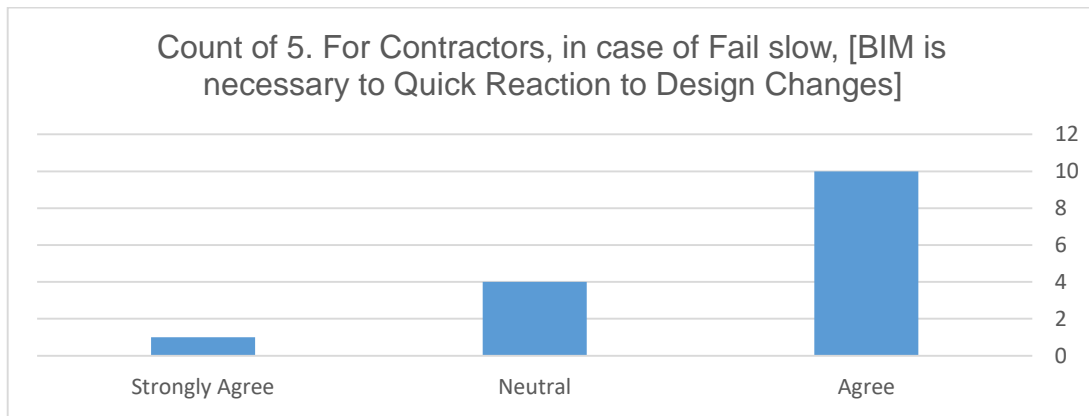


Figure 69 Contractors Questions part 5-1

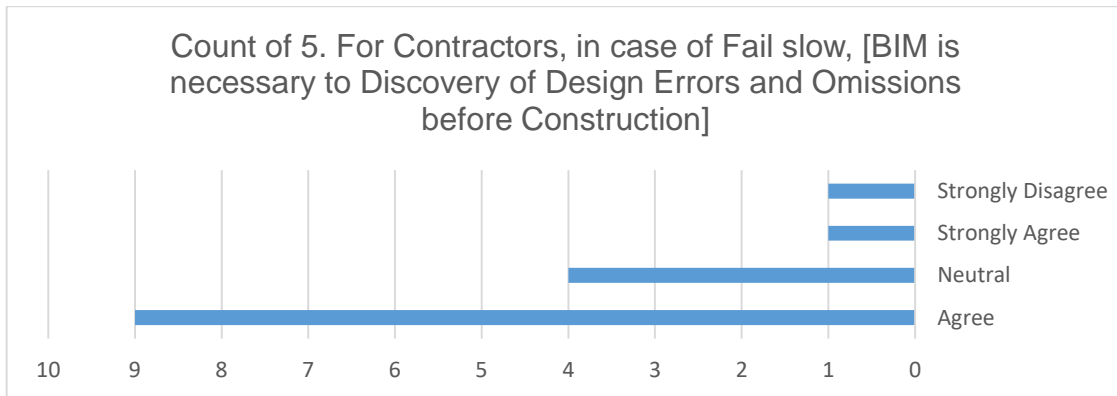


Figure 70 Contractors Questions part 5-2

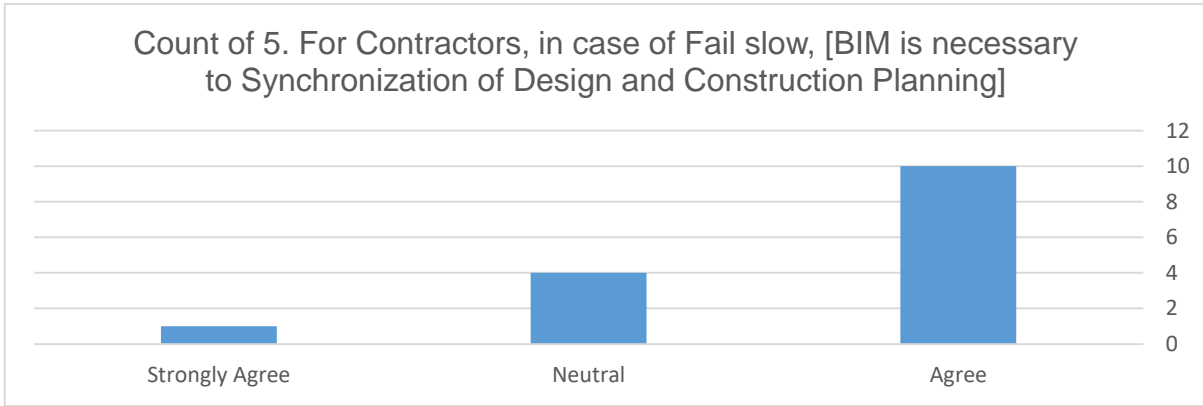


Figure 71 Contractors Questions part 5-3

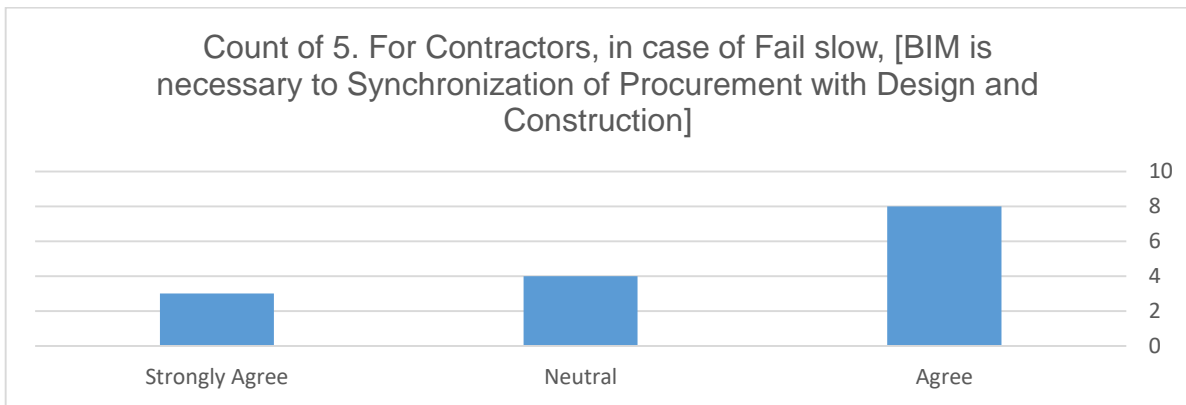


Figure 72 Contractors Questions part 5-4

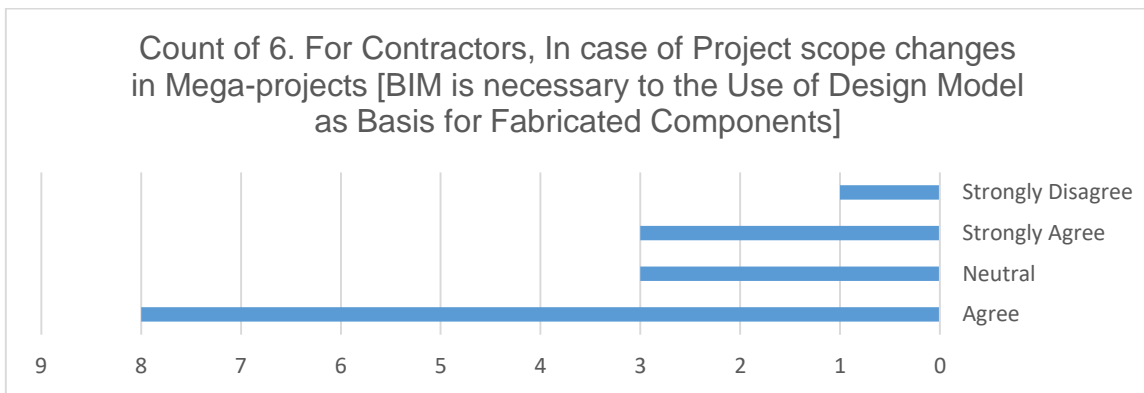


Figure 73 Contractors Questions part 6-1

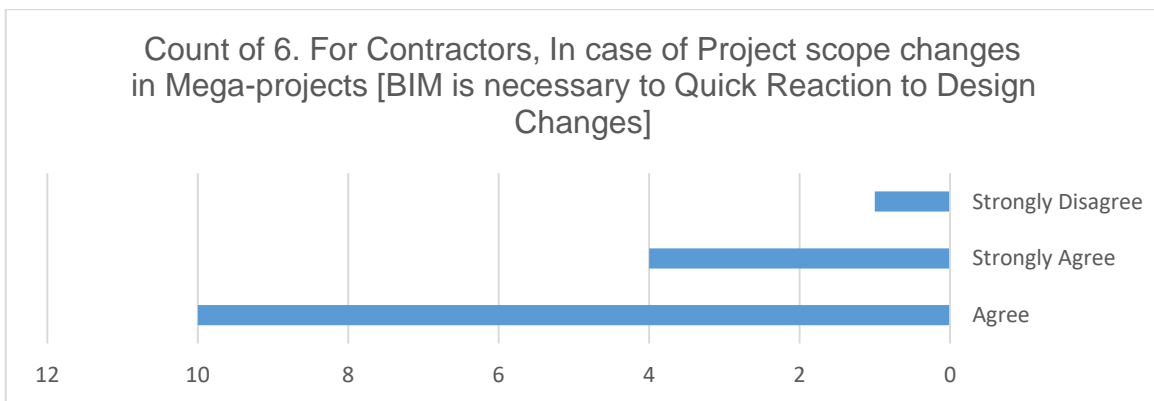


Figure 74 Contractors Questions part 6-2

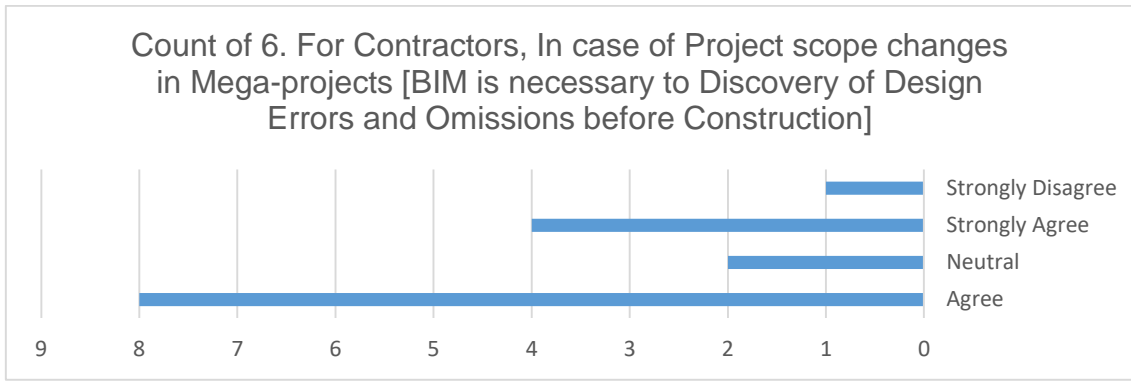


Figure 75 Contractors Questions part 6-3

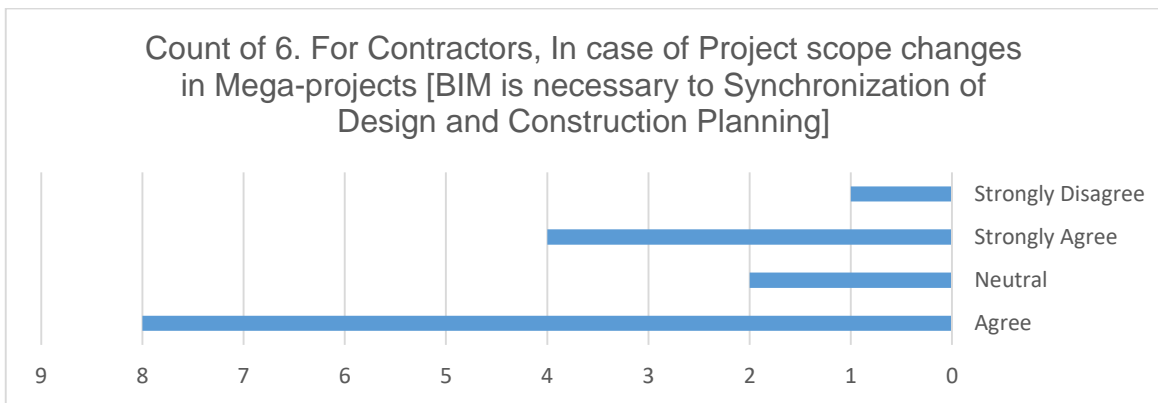


Figure 76 Contractors Questions part 6-4

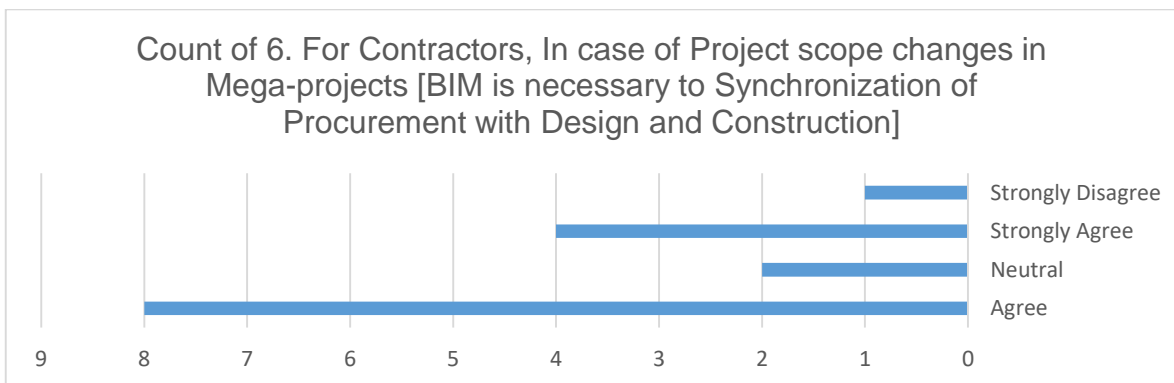


Figure 77 Contractors Questions part 6-5

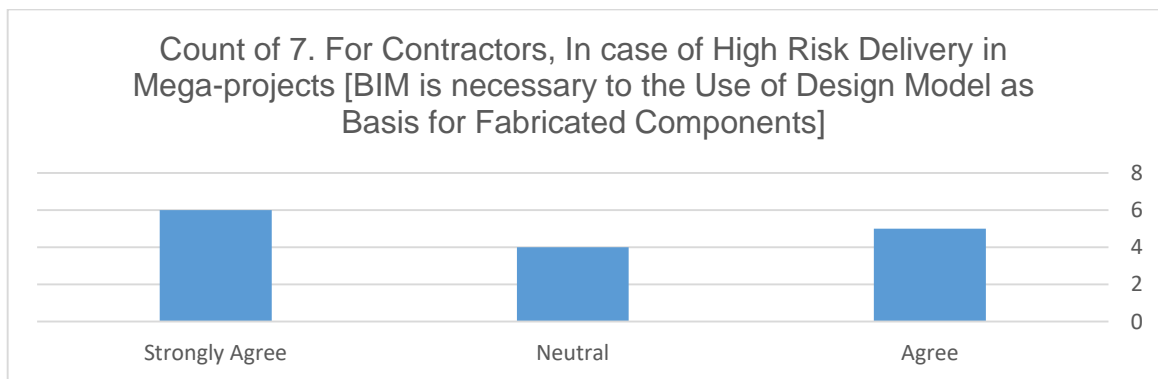


Figure 78 Contractors Questions part 7-1

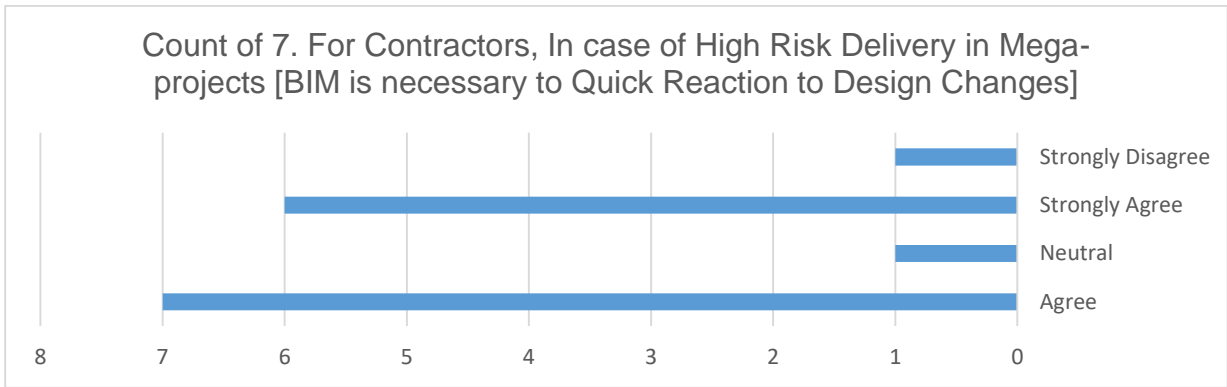


Figure 79 Contractors Questions part 7-2

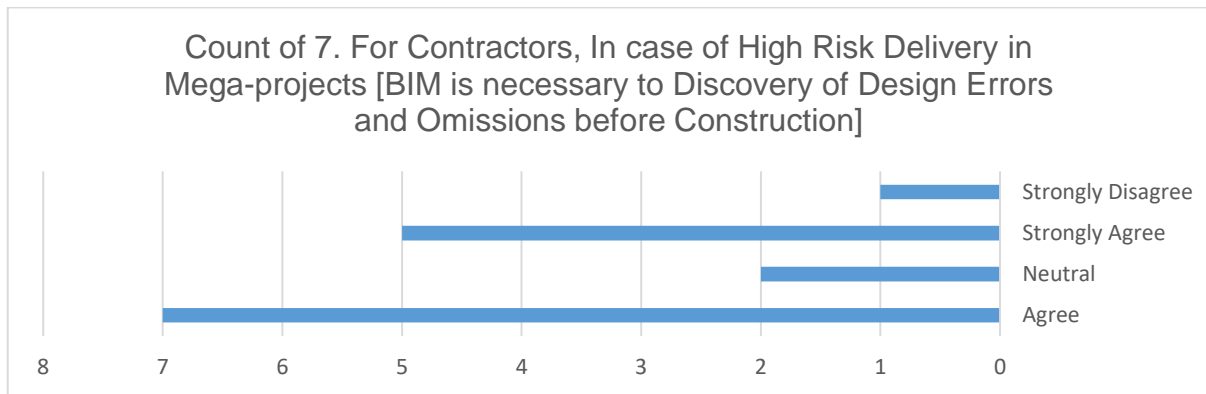


Figure 80 Contractors Questions part 7-3

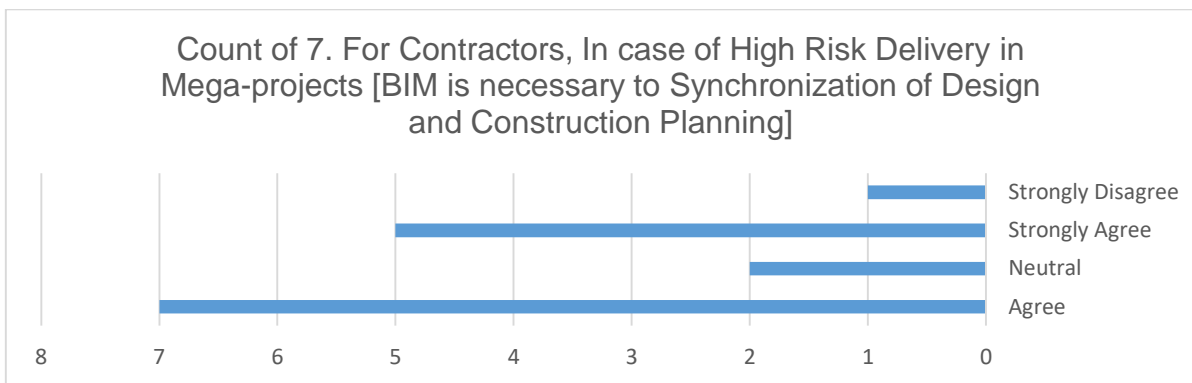


Figure 81 Contractors Questions part 7-4

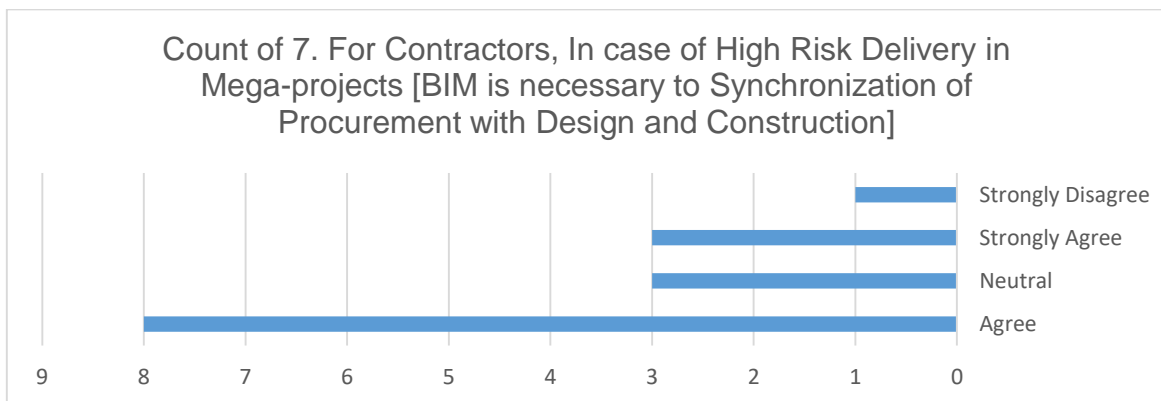


Figure 82 Contractors Questions part 7-5

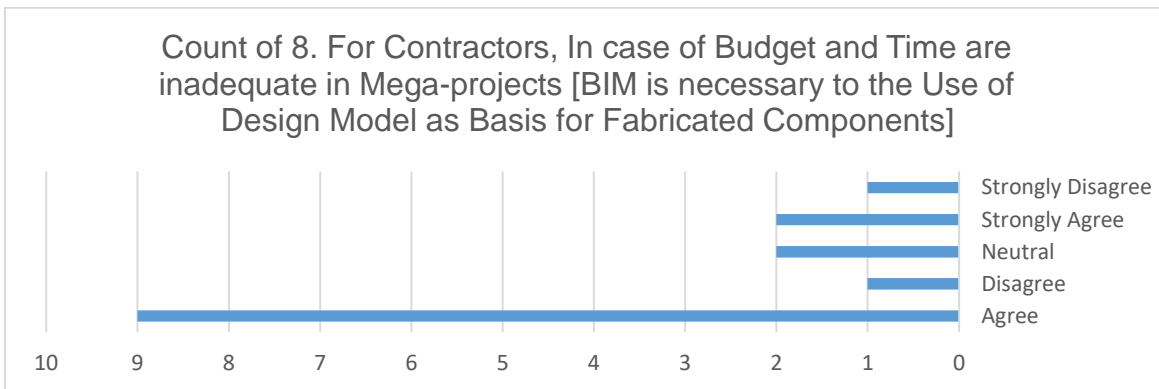


Figure 83 Contractors Questions part 8-1

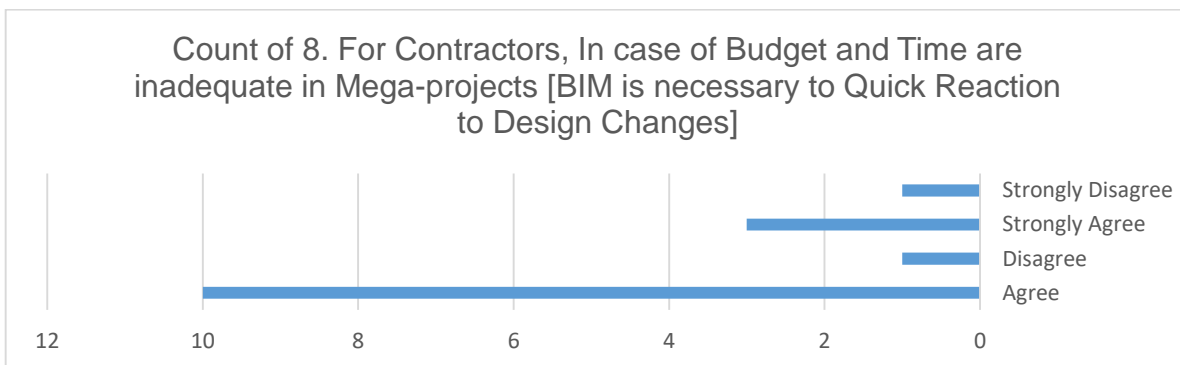


Figure 84 Contractors Questions part 8-2

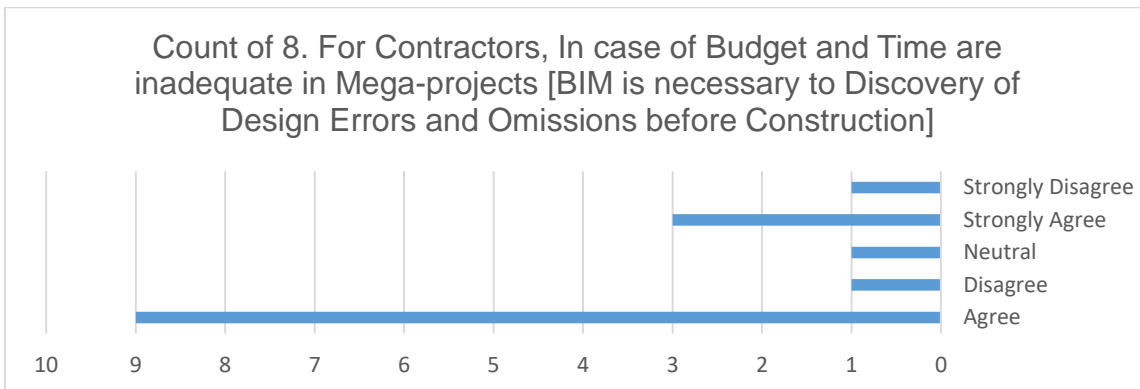


Figure 85 Contractors Questions part 8-3

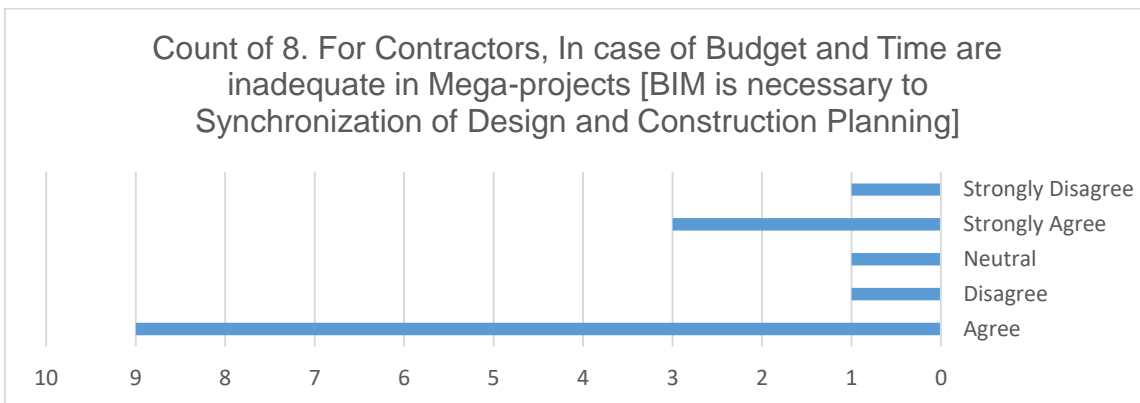


Figure 86 Contractors Questions part 8-4

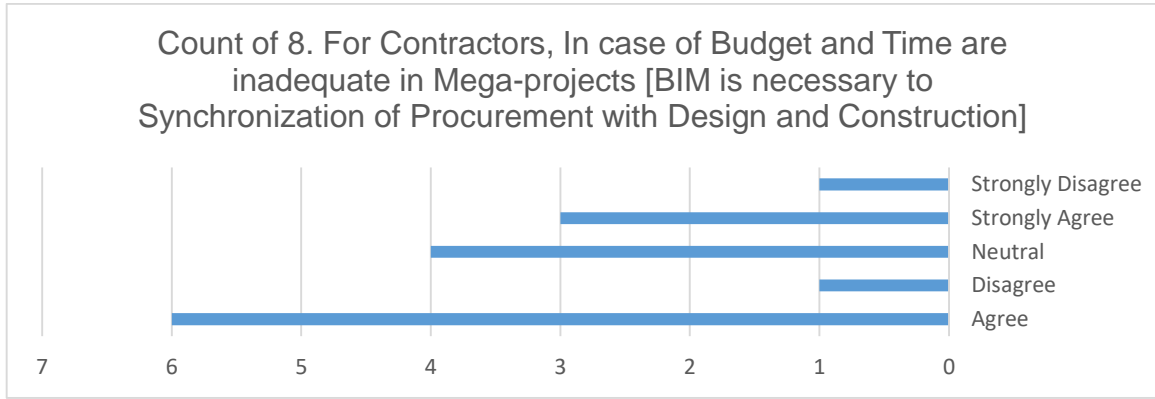


Figure 87 Contractors Questions part 8-5

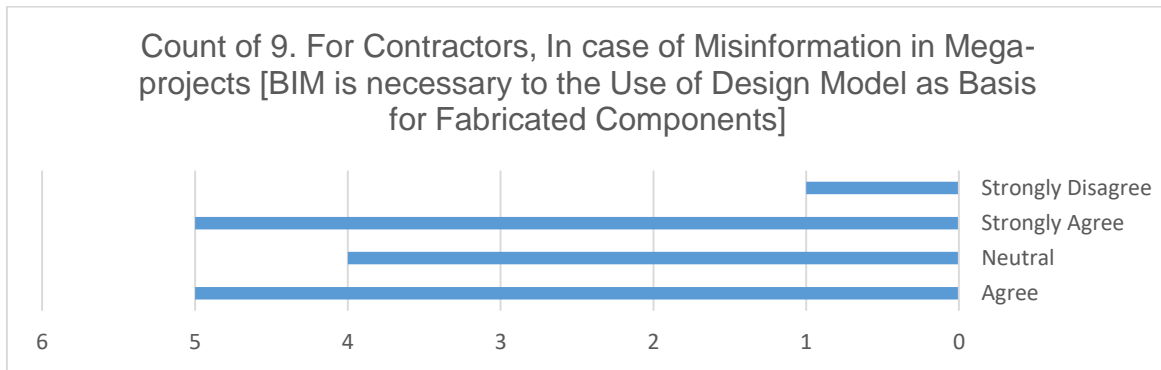


Figure 88 Contractors Questions part 9-1

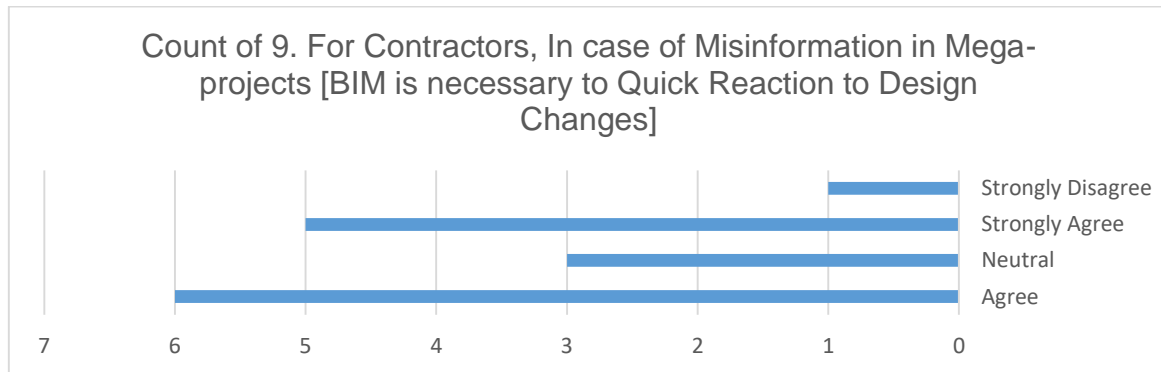


Figure 89 Contractors Questions part 9-2

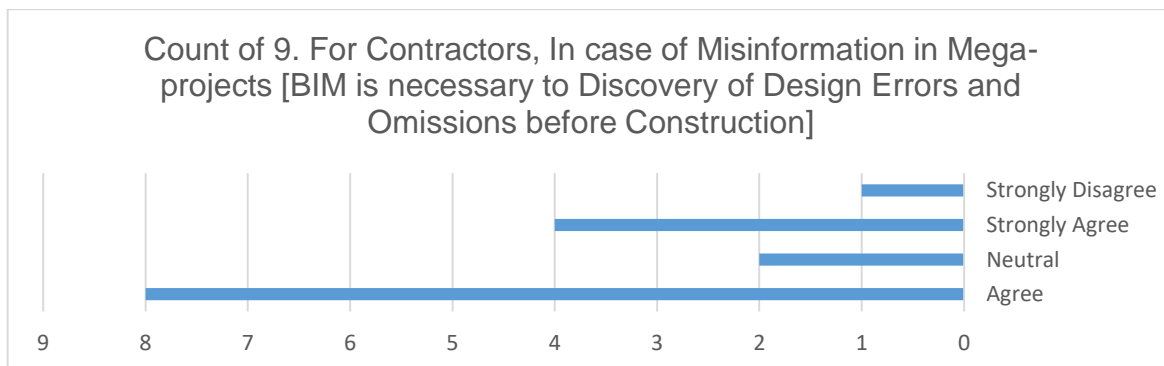


Figure 90 Contractors Questions part 9-3

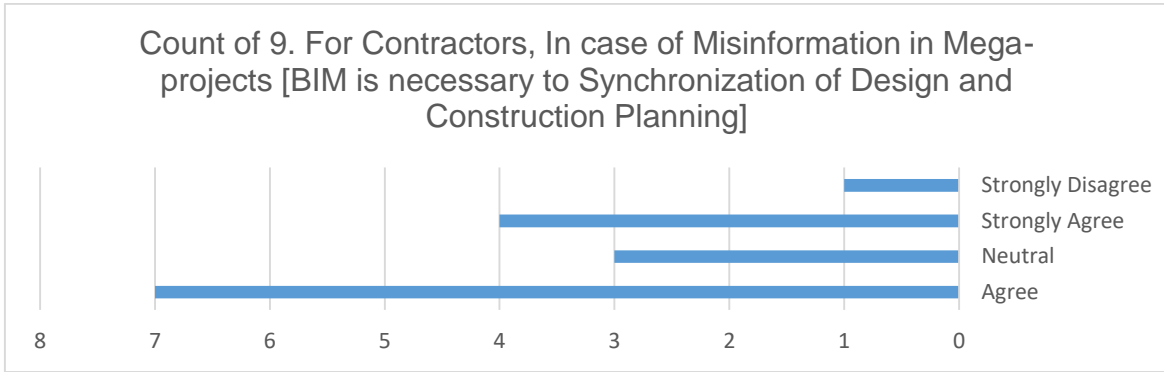


Figure 91 Contractors Questions part 9-4

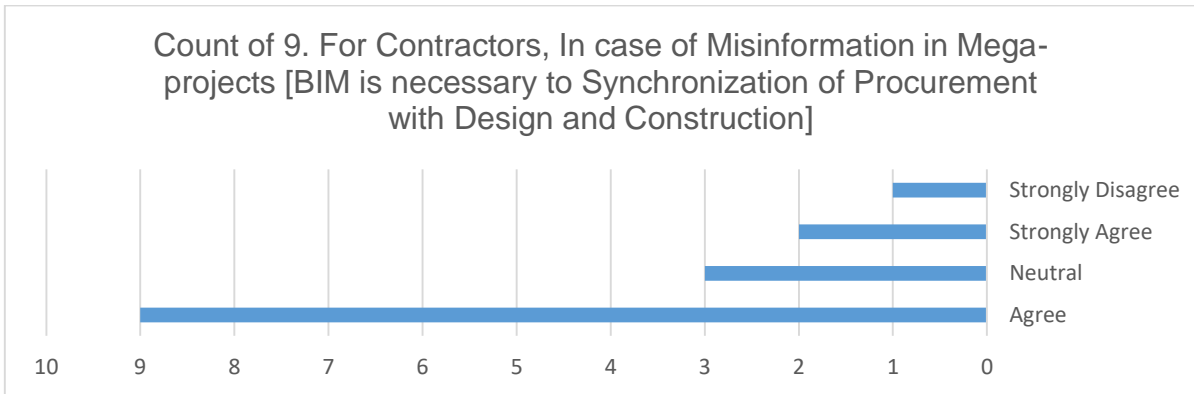


Figure 92 Contractors Questions part 9-5

- **Conclusion of Contractors & Manufacturers 'construction phases' Questions Analysis.**

	BIM Benefits											
Mega-Projects Problems		Complexity of Megaprojects	Planners change	Multi Stakeholders	uniqueness bias	Fail slow	Rent seeking	Change in project scope	High risk delivery	budget and time are inadequate	misinformation	Average
Construction and Fabrication Benefits	Use of Design Model as Basis for Fabricated Components	77%	72%					70%	78%	67%	72%	73%
	Quick Reaction to Design Changes	77%	72%	82%		70%		77%	78%	72%	73%	75%
	Discovery of Design Errors and Omissions before Construction	83%	77%		73%	65%		73%	75%	70%	73%	74%
	Synchronization of Design and Construction Planning	78%	73%	78%		70%		73%	75%	70%	72%	74%
	Better Implementation of Lean Construction Techniques	75%						73%				74%
	Synchronization of Procurement with Design and Construction	75%	73%	78%		73%		73%	70%	65%	68%	72%
Average		78%	73%	79%	73%	70%		73%	75%	69%	72%	73%

Table 9 Conclusion of Contractors & Manufacturers 'construction phases' Questions Analysis.²⁴

According to the analysis of questionnaires results for the BIM benefits influence to the Mega-projects common problems in construction and manufacturing phase, the following findings were observed:

²⁴ Reference: own tabulation

- With 65% the lowest percentage in the results table represent the discovery of design Errors and omissions before construction “BIM benefit” and its least influence to fail slow scenario, which refers to the possibility of recognize that the main streamline of the project is leading to a fail slow scenario with enhancing the same scenario without a glance to the other possible scenarios or without figuring out that this certain scenario is leading to the fail “slow” of the project.
- On the other hand discovery of design Errors and omissions before construction “BIM benefit” got 83% positive influence when it comes the complexity of mega-projects, which is showing the influence of BIM benefits is variant according to the situation or the problems, even it can create problems in the project, those points will be addressed in the next part “interviews”
- Quick reaction to design changes “BIM benefit” the changes meant here is the design changes happened during constructions and it got 82% positive influence when it comes to Multi-stakeholders problems. Also the quick reaction to design changes “BIM benefit” got the highest average percentage 75% among the other BIM benefits.
- The following two mega-projects common problems got the highest influence percentage from BIM design benefits during the construction phase:
 - Complexity of Megaprojects 78%
 - Multi-Stakeholders 79%

The level of details and the amount of information and data is increasing rapidly during the construction phase which is addressing the need for a tool to manage this big amounts of data. Also, give the ability to implement changes quickly to meet the requirements of stakeholders that can be generated after the design phase is done and during the construction or even the commissioning phase.

- budget and time are Inadequate “Mega-project problem” got the least influence of BIM benefits in construction phase with 69% while the same problem in design phase got 74% positive influence which meets with the figure showed before in chapter 3 where the influence curve is decreasing with time going forward.
- With the same concept of the reduction of influence with the progress of time in the project life cycle, 73% overall average positive influence of BIM benefits to mega-projects common problems during construction and manufacturing phase

which was 77% overall in the design phase. It is highlighting the need to implement BIM as early as possible in the project without considering the cost of implementation because the value of information stored on BIM database is increasing with time even if the influence is less.

5.2.3.5 Facility managers 'Post Construction phases' Questions analysis

How far do you agree with the following statements?

Only one respond in this section and the answers 50% agree and 50% neutral.

In this part in the final matrix results, the results of the questionnaires will not be considered because of the low number of participants. The results of the interviews only will be considered.

5.3 Interviews

5.3.1 1st Interview: Salah Omar Omran

BIM Manager at Turner International Middle East, PHD Candidate, MSc, Autodesk Certified Instructor, ACP, ASA, BIM-RICS

Date: 2nd July 2018

On-line Interview

Topic: Mega-projects problems & BIM benefits

The Interview started in a sequence following the problems and the related benefits of BIM that can contribute to solve the problems, the interviewee is currently holding the position of BIM Manager in a Mega-project in Kuwait "One of the Largest Educational Campuses in the World" *Sabah Al Salem University City*

- **Megaprojects are unstable because the long planning vision and details.**

"The later BIM is implemented in the project, the less benefits that the project gets" that sentence was the first respond of Salah Omran after reviewing the Mega-projects problems & BIM benefits Matrix.

In the development design stage, BIM value can be easily notices when discussing the complexity nature of Mega-projects which needs conceptual design options visualization that the traditional design tools doesn't offer or it does, but with much time needed

and in some certain levels of complexity, the traditional design tools will not be able to offer the desired results. Implementing BIM at the early stage of Design development has a positive impact to the owner benefits with about 80% in average, and according to Salah feedback the most beneficial impact of BIM is the increase of building performance and overall quality of the project. Then Salah referred to less positive impact regarding the collaboration between the complicated disciplines of the project using integrated project delivery because of the number of individuals Involved in the process, Yes BIM has a positive impact in the point, but finally it is related to individual's behaviors.

	BIM Benefits		Overall benefits for the owner when using BIM to handle the Complexity of Mega-projects
Mega-Projects Problems		Complexity of Megaprojects	
Benefits to Owner	Concept, Feasibility, Design Benefits	80%	80%
	Increased Building Performance and Quality	90%	
	Improved Collaboration Using Integrated Project Delivery	70%	

Table 10 BIM benefits to the owner regarding the complexity of Mega-projects "Salah interview"²⁵

In the project design phase, Salah refer to the high importance of BIM for design visualization and the ability of visualize it earlier and more accurate than the previous design tools, especially when it comes to the complexity mixture of disciplines in Mega-projects. However, when it comes to Automatic low-level correction in design, the traditional design tool was offering almost the same option, to bring it to light, the automatic low level correction in the traditional design tools, like in AutoCAD, there is an option to delete all the lines which is less than a certain length, or to use the Purge option to delete most of the unused items or non-assigned items from the CAD file, BIM as well has a positive impact then the automatic low level corrections, but not with a significant benefits than the traditional tools.

²⁵ Reference: own tabulation

	BIM Benefits		Overall benefits for Design when using BIM to handle the Complexity of Megaprojects
Mega-Projects Problems		Complexity of Megaprojects	
Design Benefits	Earlier and More Accurate Visualizations of a Design	100%	85%
	Automatic Low-Level Corrections	60%	
	Generation of Accurate and Consistent 2D Drawings	90%	
	Earlier Collaboration of Multiple Design Disciplines	80%	
	Easy Verification of Consistency to the Design Intent	80%	
	Extraction of Cost Estimates during the Design Stage	90%	
	Improvement of Energy Efficiency and Sustainability	90%	

Table 11 Design, BIM benefits regarding the complexity of Mega-projects "Salah interview"²⁶

When it come to the earlier and more accurate visualizations of design, Salah assured the significant positive impact that BIM did in the design phase, also referring to the positive impact to generation of accurate of 2d drawings, this point will be reviewed in the next interview from a totally different point of view.

Salah admitted the importance of BIM in the earlier collaboration of multiple design disciplines, but he referred to the relation between the lake of talented professionals and the quality of the collaboration process. The easy and accurate cost estimation extraction that can be done with BIM through the design phase has a high impact to decide changes and modifications in design phase, but the accuracy of the cost estimation is related to the level of details and the accurate information added to the models. When it comes to the energy efficiency and sustainability, Salah referred to most of the companies working in the field of energy are modeling all the details in the project even if it not a mandatory requirement. Through design phase, BIM offers many design options and simulation tools such as sun and wind locations and directions. To give an example from the current Mega-project where he works currently *Sabah Al Salem University City* "One of the Largest Educational Campuses in the World" he mentioned that the day light analysis was done by using BIM models and tools. In overall Salah

²⁶ Reference: own tabulation

estimates the benefits of BIM in Complex Mega-projects design phase with 85% more efficient than the previous traditional tools that were used before to develop mega-projects designs.

	BIM Benefits		Overall benefits for Design when using BIM to handle the Complexity of Mega-projects
Mega-Projects Problems		Complexity of Megaprojects	
Construction and Fabrication Benefits	Use of Design Model as Basis for Fabricated Components	80%	85%
	Quick Reaction to Design Changes	95%	
	Discovery of Design Errors and Omissions before Construction	95%	
	Synchronization of Design and Construction Planning	70%	
	Synchronization of Procurement with Design & Construction	90%	

Table 12 Construction & Fabrication, BIM benefits regarding the complexity of Mega-projects "Salah interview"²⁷

In construction and fabrication phase, when it comes to use the design model as basis for fabricated components such as windows, doors, ducting, cable trays... Salah agreed with 80% to that because it depends about the level of details that the model has and the accuracy of this details to use it in fabrications. In the same time, he referred to the reinforcement details in the concrete where BIM is giving a perfect details and cutting list for each member. Although, the construction already started but changes in design still can happen and using BIM with the complex details in the mega-projects is giving a significant benefit that Salah give is 95% but not 100% because the human error is still exist.

Conflicts and construction problems are spotted before it can implemented in the field. Coordination between involved designers and contractors is improved and errors of omission are reduced. This accelerate the construction process, save time and reduces costs. Salah referred to the significant benefit of BIM to discover the errors earlier than it can happen.

²⁷ Reference: own tabulation

Synchronization of design, procurement and construction Planning were significantly improved as the changes that happen in the model can be changed immediately in the schedule if they are connected and the changes that happen in the schedule can be changed in the model as it is synchronized together. Salah referred to the procurement lists that can be generated for the BIM model to make the required purchasing lists of most of the project elements, also if any changes were made to the design it will immediately change in the generated new purchasing lists, if an extra purchasing happened it will be considered a loss of budget and if the purchased amount was fewer than required it will delay the work waiting for the next delivery.

Overall benefits for Construction and fabrication phase when using BIM to handle the Complexity of Megaprojects, Salah estimates it as 85% because of the human error and the conflicts that can happen between the project participants themselves.

“The more the project goes into details the more the value of benefits that it gets from BIM” Salah Omar Omran 2nd July 2018.

	BIM Benefits		Overall benefits for Design when using BIM to handle the Complexity of Megaprojects
Mega-Projects Problems		Complexity of Megaprojects	
Post Construction Benefits	Improved Commissioning & Handover of Facility Info.	95%	92%
	Better Management and Operation of Facilities	90%	
	Integration with Facility Operation and Management Systems	90%	

Table 13 Post construction, BIM benefits regarding the complexity of Mega-projects "Salah interview"²⁸

“The earlier BIM is implemented the more benefits that the project get in the advanced stages specially post construction stages, BIM model is full of information through the whole project life cycle” Salah Omar Omran 2nd July 2018.

However the construction is done, but the commissioning and integration between the project disciplines is not done yet, and in the case of Mega-projects, it has a long list of disciplines and the bigger array of connections between them. Having all the information at this stage in one pocket make the process of handing over smoother and

²⁸ Reference: own tabulation

takes less time, avoiding missing of important information that was collected throughout the project life cycle and very important for the post construction stage. Here Salah give 95% and he referred to the other software and tools which are used for facility management that is not BIM tools, but in the same time you still have all the inputs available in one pocket which is BIM models. Finally, BIM has positive impact and benefits of 85% to the Megaprojects unstable planning process and complex interfaces through the different phases of the project life cycle and the benefits are variant between the participants of the project. However it is costly to implement still the benefits and the return of implementing is much more and not even comparable to the small budget invested for training and utilities.

- **Project team changes effects to Mega-projects and BIM influence.**

However, stability of the project participants and project time is very important especially in Mega-projects but due to the long planning schedule for Mega-projects project team may change multiple times through the project life cycle and it is difficult to bridge between the old and the new members especially in case of complex and variety of details in Mega-project. When the discussion started with Salah, he referred to the stability of the project team in his project, but the changes still can happened and can create major troubles in case of managers changed.

	BIM Benefits		Overall benefits for the owner when using BIM to handle Project team changes in Megaprojects
Mega-Projects Problems		Planners change	
Benefits to Owner	Concept, Feasibility, Design Benefits	50%	60%
	Increased Building Performance and Quality	50%	
	Improved Collaboration Using Integrated Project Delivery	80%	

Table 14 BIM benefits to the owner regarding Project team changes in Mega-projects "Salah interview"²⁹

In the development design phase, the team of the project consist of designers and planners, and the project level of details still low level. Using BIM has an advantage as it saves all the information in one place and offers an easy access to this information. The amount of information in this phase is not a huge amount so in this case BIM

²⁹ Reference: own tabulation

influence is not as significant as the later phases when it comes to the effect of the project team changes in design development phase. The stability of the project team is always an advantage, however the changes still happens and when the new member or team start to handle the project, Salah referred to 50% positive effect of that, but in the same time Salah referred to the more positive influence of BIM when it comes to the collaboration using integrated project delivery. Finally Salah estimates the positive influence of BIM in Mega-projects development phase as 60% in case it happened.

	BIM Benefits		Overall benefits for Design when using BIM to handle Project team changes in Megaprojects
Mega-Projects Problems		Planners change	
Design Benefits	Earlier and More Accurate Visualizations of a Design	80%	87%
	Generation of Accurate and Consistent 2D Drawings	90%	
	Earlier Collaboration of Multiple Design Disciplines	90%	
	Extraction of Cost Estimates during the Design Stage	90%	

Table 15 Design, BIM benefits regarding Project team changes in Mega-projects "Salah interview"³⁰

Here, in the Design phase, it is noticeable that the positive influence percentage increase which Salah admits that the increase in project details make the problem of project team changes affects more to the work flow negatively, as well when hiring the new members or the new time it will take time to review and understand the project details. With BIM it makes it significantly easier and less time consuming than reviewing 2D drawings.

³⁰ Reference: own tabulation

	BIM Benefits		Overall benefits for Construction when using BIM to handle Project team changes in Megaprojects
Mega-Projects Problems		Planners change	
Construction and Fabrication Benefits	Use of Design Model as Basis for Fabricated Components	90%	90%
	Quick Reaction to Design Changes	90%	
	Discovery of Design Errors and Omissions before Construction	90%	
	Synchronization of Design and Construction Planning	90%	
	Synchronization of Procurement with Design & Construction	90%	

Table 16 Construction and Fabrication, BIM benefits regarding Project team changes in Mega-projects "Salah inter-view"³¹

In case of project team members changes in the construction phase, where the level of information of the project is higher and especially in high information content of Mega-projects, Salah gives 90% positive influence to BIM in this stage, because of the amount of coordinated information that can be stored in BIM models and the time savings for the new team members to make an overview for the whole project in the beginning, while in 2D drawings, it is time consuming process.

	BIM Benefits	
Mega-Projects Problems		Planners change
Post Construction Benefits	Improved Commissioning and Handover of Facility Information	98%

Table 17 Post Construction, BIM benefits regarding Project team changes in Mega-projects "Salah inter-view"

Salah keeps the same concept of BIM as a storage of coordinated information, and in case BIM implemented from the early beginning of the project, it gains the maximum positive influence to the project in the commissioning and handing over phases.

³¹ Reference: own tabulation

- **Multi Stakeholders effects to Mega-projects and BIM influence.**

	BIM Benefits		Overall benefits for owner when using BIM to handle Multi Stakeholders in Megaprojects
Mega-Projects Problems		Multi Stakeholders	
Benefits to Owner	Concept, Feasibility, Design Benefits	95%	95%
	Improved Collaboration Using Integrated Project Delivery	95%	

Table 18 BIM benefits to the owner regarding Multi Stakeholders management in Mega-projects "Salah interview"³²

Especially in Mega-projects, there are multi stakeholders and in this case in the early design phase, the designers need to satisfy the requirements of all the stake holders. BIM offers the design options and building different scenarios for the projects with minimum effort comparing to the traditional design tools.

	BIM Benefits		Overall benefits for Design when using BIM to handle Multi Stakeholders in Mega-projects
Mega-Projects Problems		Multi Stakeholders	
Design Benefits	Earlier and More Accurate Visualizations of a Design	80%	80%
	Easy Verification of Consistency to the Design Intent	80%	

Table 19 BIM benefits to Design regarding Multi Stakeholders management in Mega-projects "Salah interview"³³

In the detailed design phase, Salah gives a lower percentage for BIM positive influence because the level of information is going up with time and the time and effort needed to make changes are higher, and not easy as it was in concept design phase. As well because of the lower number of stake holders comparing to construction phase.

³² Reference: own tabulation

³³ Reference: own tabulation

	BIM Benefits		Overall benefits for Construction & Fabrication using BIM to handle Multi Stakeholders in Megaprojects
Mega-Projects Problems		Multi Stakeholders	
Construction and Fabrication Benefits	Quick Reaction to Design Changes	90%	90%
	Synchronization of Design and Construction Planning	90%	
	Synchronization of Procurement with Design & Construction	90%	

Table 20 BIM benefits to Construction and Fabrication regarding Multi Stakeholders management in Mega-projects "Salah interview"³⁴

In the construction and fabrication phase in megaprojects, there is a huge numbers of stake holder (owner, designers, planners, contractors, suppliers...) and a higher level of information and details. Salah gives again a higher percentage because of the flexibility BIM allows the whole project team to make changes and deliver the new information to a huge number of individuals involved in the project and coordinated in the same time. BIM clouds is one of the best solutions for this case.

	BIM Benefits	
Mega-Projects Problems		Multi Stakeholders
Post Construction Benefits	Integration with Facility Operation and Management Systems	80%

Table 21 BIM Post Construction benefits regarding Multi Stakeholders management in Mega-projects "Salah interview"³⁵

In the post construction phase, the whole project needs to be coordinated and testing for the operations. Some of stake holders are leaving the project and new stake holders are ready to join. Facility managers and users are the new joining stake holders. Salah refer to the other tools and software that are used for facility management. However BIM is still has a high importance as a coordinated data bank for the facility.

³⁴ Reference: own tabulation

³⁵ Reference: own tabulation

- **Uniqueness Bias effect to Mega-projects and BIM influence.**

	BIM Benefits		BIM influence to Uniqueness bias in Mega-projects
Mega-Projects Problems		uniqueness bias	
Design Benefits	Earlier and More Accurate Visualizations of a Design	40%	40%
	Easy Verification of Consistency to the Design Intent	40%	

Table 22 BIM Design influence to Uniqueness Bias in Mega-projects "Salah interview"³⁶

Salah didn't give a high positive influence to BIM benefits in the case of uniqueness bias. Because this situation depends on the project team spiritual condition that doesn't allow them to see the project alternatives scenarios. However BIM is still provide positive influence by the early accurate visualization of the design and the verification of design intent.

	BIM Benefits	
Mega-Projects Problems		uniqueness bias
Construction and Fabrication Benefits	Discovery of Design Errors and Omissions before Construction	40%

Table 23 BIM Construction influence to Uniqueness Bias in Mega-projects "Salah interview"³⁷

In construction and fabrication phase, the only BIM benefit has influence to uniqueness bias problem is the discovery of design errors and omissions before construction. Salah refer to the pervious reason while giving 40%.

- **Fail slow effect to Mega-projects and BIM influence.**

	BIM Benefits	
Mega-Projects Problems		Fail slow
Benefits to Owner	Concept, Feasibility, Design Benefits	50%

Table 24 Owner benefits of BIM influence to fail slow concept in Mega-projects "Salah interview"³⁸

³⁶ Reference: own tabulation

³⁷ Reference: own tabulation

³⁸ Reference: own tabulation

Salah was in the middle when he mentioned the BIM influence to fail slow scenario as the project team commitment to one path of the project can happen even in the early concept design phase. Sometimes the designers follow the owner thinking path without addressing the alternatives and it is a failing path.

	BIM Benefits		BIM influence to Fail Slow concept in Megaprojects "Design"
Mega-Projects Problems		Fail slow	
Design Benefits	Earlier and More Accurate Visualizations of a Design	40%	40%
	Automatic Low-Level Corrections	40%	
	Earlier Collaboration of Multiple Design Disciplines	40%	
	Easy Verification of Consistency to the Design Intent	40%	
	Extraction of Cost Estimates during the Design Stage	40%	

Table 25 Design benefits of BIM influence to fail slow concept in Mega-projects "Salah interview"³⁹

When the project goes to the detailed design phase, the project team commitment to one path of the project is increasing. BIM allows visualization and disciplines collaboration, however on the project strategic level the one path commitment still exist and the designers who have the knowledge are not reporting the alternatives to the decision makers.

	BIM Benefits		BIM influence to Fail Slow concept in Megaprojects "Construction"
Mega-Projects Problems		Fail slow	
Construction and Fabrication Benefits	Quick Reaction to Design Changes	30%	30%
	Discovery of Design Errors and Omissions before Construction	30%	
	Synchronization of Design and Construction Planning	30%	
	Synchronization of Procurement with Design & Construction	30%	

Table 26 Construction benefits of BIM influence to fail slow concept in Mega-projects "Salah interview"

³⁹ Reference: own tabulation

With the level of influence is decreasing and the level of information “for the committed path” is increasing, the chances for BIM benefits to open the stake holders eyes to the fail slow path is lower. As BIM as a tool is used now to go deeper into the committed path. And the changes in this phase are very critical.

- **Project scope changes effect to Mega-projects and BIM influence.**

	BIM Benefits	
Mega-Projects Problems		Change in project scope
Benefits to Owner	Concept, Feasibility, Design Benefits	90%

Table 27 Owner benefits of BIM influence to Project scope changes in Mega-projects "Salah interview"⁴⁰

For the project scope changes, Salah refer to the savings of time and effort by using BIM in concept design phase. As the changes can be done much easier than the traditional design methods even if this change was a change in the project scope.

	BIM Benefits		BIM influence to Project scope changes during Design in Mega-projects
Mega-Projects Problems		Change in project scope	
Design Benefits	Earlier and More Accurate Visualizations of a Design	90%	90%
	Earlier Collaboration of Multiple Design Disciplines	90%	
	Easy Verification of Consistency to the Design Intent	90%	
	Extraction of Cost Estimates during the Design Stage	90%	

Table 28 Design benefits of BIM influence to Project scope changes in Mega-projects "Salah interview"⁴¹

In detailed design phase and for designers as well, Salah kept the same opinion about the design options and the flexibility to make changes to the design with much less effort and time by using BIM even in the case of mega-projects with higher level of complex details.

⁴⁰ Reference: own tabulation

⁴¹ Reference: own tabulation

	BIM Benefits		BIM influence to Project scope changes during Construction in Megaprojects
Mega-Projects Problems		Change in project scope	
Construction and Fabrication Benefits	Use of Design Model as Basis for Fabricated Components	90%	90%
	Quick Reaction to Design Changes	90%	
	Discovery of Design Errors and Omissions before Construction	90%	
	Synchronization of Design and Construction Planning	90%	
	Better Implementation of Lean Construction Techniques	90%	
	Synchronization of Procurement with Design & Construction	90%	

Table 29 Construction & Fabrication benefits of BIM influence to Project scope changes in Mega-projects "Salah interview"⁴²

In the construction phase, Salah kept the same positive attitude towards the possible changes in project scope, however he refer to the time that the execution of changes can takes.

- **High-risk delivery of Mega-projects and BIM influence.**

	BIM Benefits		BIM influence to High-Risk delivery in Megaprojects
Mega-Projects Problems		High risk delivery	
Design Benefits	Automatic Low-Level Corrections	60%	60%
	Earlier Collaboration of Multiple Design Disciplines	60%	

Table 30 Design benefits of BIM influence to High-Risk Delivery Mega-projects "Salah interview"⁴³

Salah said that BIM is assisting the discovery of possible risks which will influence the detailed design phase with possible changes. However when the risk is accepted BIM still can reduce the negative impact of the risks by the early collaboration and the automatic corrections but still not a high positive influence.

⁴² Reference: own tabulation

⁴³ Reference: own tabulation

	BIM Benefits		BIM influence to High-Risk delivery in Megaprojects
Mega-Projects Problems		High risk delivery	
Construction and Fabrication Benefits	Use of Design Model as Basis for Fabricated Components	70%	75%
	Quick Reaction to Design Changes	70%	
	Discovery of Design Errors and Omissions before Construction	70%	
	Synchronization of Design and Construction Planning	80%	
	Synchronization of Procurement with Design and Construction	80%	

Table 31 Construction benefits of BIM influence to High-Risk Delivery Mega-projects "Salah interview"⁴⁴

In the construction phase while the level of influence is less and the level of information is higher. The project team can see risks clearer than the design phase. Salah gives BIM a higher level of positive influence than in design phase due to the flexibility, coordination and synchronization abilities of BIM. In average 75% positive influence of BIM to the high risk delivery of mega-projects.

	BIM Benefits	
Mega-Projects Problems		High risk delivery
Post Construction Benefits	Improved Commissioning and Handover of Facility Information	80%

Table 32 Post Construction benefits of BIM influence to High-Risk Delivery Mega-projects "Salah interview"⁴⁵

In the post construction phase, Salah followed his main stream about BIM as a storage of coordinated data and the value of this cumulative data is increasing with time, so the higher value is at the end by 80%. BIM improved the commissioning and handing over phase in case of high risk delivery.

⁴⁴ Reference: own tabulation

⁴⁵ Reference: own tabulation

- **Inadequate time & budget.**

	BIM Benefits	
Mega-Projects Problems		budget and time are inadequate
Benefits to Owner	Concept, Feasibility, Design Benefits	50%

Table 33 Owner benefits of BIM influence to inadequate time & budget in Mega-projects "Salah interview"⁴⁶

In the early concept design phase, the project can be not feasible and the initial budget and time are inadequate, however it is the owner decision to go on with the project. The hiding hand principle is playing a big rule in this stage as discussed before. Salah was in the middle regarding the influence of BIM here as BIM can tell if the budget and time are adequate or not, but it cannot take the decision to go on with the project.

	BIM Benefits		BIM influence to inadequate time & budget in Mega-projects
Mega-Projects Problems		budget and time are inadequate	
Design Benefits	Earlier and More Accurate Visualizations of a Design	50%	50%
	Easy Verification of Consistency to the Design Intent	50%	
	Extraction of Cost Estimates during the Design Stage	50%	

Table 34 Design benefits of BIM influence to inadequate time & budget in Mega-projects "Salah interview"⁴⁷

In the detailed design phase, the same stream will continue.

⁴⁶ Reference: own tabulation

⁴⁷ Reference: own tabulation

	BIM Benefits		BIM influence to inadequate time & budget in Mega-projects
Mega-Projects Problems		budget and time are inadequate	
Construction and Fabrication Benefits	Use of Design Model as Basis for Fabricated Components	50%	50%
	Quick Reaction to Design Changes	50%	
	Discovery of Design Errors and Omissions before Construction	50%	
	Synchronization of Design and Construction Planning	50%	
	Synchronization of Procurement with Design and Construction	50%	

Table 35 Construction benefits of BIM influence to inadequate time & budget in Mega-projects "Salah interview"⁴⁸

In the construction phase, of course BIM has a positive influence to the project time and budget. However in the case of inadequate time and budget from the early beginning of the project, BIM will not change in the whole picture.

- **Misinformation**

	BIM Benefits		BIM influence to Misinformation in Megaprojects
Mega-Projects Problems		misinformation	
Benefits to Owner	Concept, Feasibility, Design Benefits	90%	90%
	Increased Building Performance and Quality	90%	
	Improved Collaboration Using Integrated Project Delivery	90%	

Table 36 Owner benefits of BIM influence to Misinformation in Mega-projects "Salah interview"⁴⁹

⁴⁸ Reference: own tabulation

⁴⁹ Reference: own tabulation

	BIM Benefits		BIM influence to Misinformation in Megaprojects
Mega-Projects Problems		misinformation	
Design Benefits	Earlier and More Accurate Visualizations of a Design	90%	90%
	Easy Verification of Consistency to the Design Intent	90%	
	Extraction of Cost Estimates during the Design Stage	90%	

Table 37 Design benefits of BIM influence to Misinformation in Mega-projects "Salah interview"⁵⁰

	BIM Benefits		BIM influence to Misinformation in Megaprojects
Mega-Projects Problems		misinformation	
Construction and Fabrication Benefits	Use of Design Model as Basis for Fabricated Components	90%	90%
	Quick Reaction to Design Changes	90%	
	Discovery of Design Errors and Omissions before Construction	90%	
	Synchronization of Design and Construction Planning	90%	
	Synchronization of Procurement with Design and Construction	90%	

Table 38 Construction benefits of BIM influence to Misinformation in Mega-projects "Salah interview"⁵¹

For Misinformation as a problem in itself, not as a source of other problems. Salah refer to his main concept about BIM as a data bank for easy access coordinated information which its value increases during the project lifecycle and especially if implemented from the early beginning of the project.

	BIM Benefits		BIM influence to Misinformation in Megaprojects
Mega-Projects Problems		misinformation	
Post Construction Benefits	Improved Commissioning and Handover of Facility Information	80%	80%
	Better Management and Operation of Facilities	80%	
	Integration with Facility Operation and Management Systems	80%	

Table 39 Post Construction benefits of BIM influence to Misinformation in Mega-projects "Salah interview"⁵²

⁵⁰ Reference: own tabulation

⁵¹ Reference: own tabulation

⁵² Reference: own tabulation

In the post construction phase, Salah lower the positive influence of BIM with 10% because he refer to the other programs and software already used for facility management. The information transfer between BIM and those facility management programs let the chance for some information leakage.

5.3.2 2nd Interview: Ayman Essawy

Head of BIM Unit, Projacs International, Kuwait, RICS certified BIM Manager, Autodesk Certified Instructor.

Date: 15th July 2018

On-line Interview

Topic: Mega-projects problems & BIM benefits

The Interview started in a sequence following the problems and the related benefits of BIM that can contribute to solve the problems, the interviewee is currently holding the position of Head of BIM Unit, Projacs International and with more than 11 years' experience in both contractor and consultant in Mega-projects.

It was noticed during the interview that Ayman is wearing the contractor glasses most of the time, and it is really beneficial to the whole discussion. It happened many times that Ayman referred to the problems that can be created because of the implementation of BIM.

- BIM Benefits – Mega-projects Problems Matrix. “Contractor point of view”

	BIM Benefits										
Mega-Projects Problems		Complexity of Megaprojects	Planners change	Multi Stakeholders	uniqueness bias	Fail slow	Rent seeking	Change in project scope	High risk delivery	budget and time are inadequate	misinformation
Benefits to Owner	Concept, Feasibility, Design Benefits	100%	60%	70%		50%		80%			
	Increased Building Performance and Quality	80%	60%								
	Improved Collaboration Using Integrated Project Delivery	80%	60%	70%							
Design Benefits	Earlier and More Accurate Visualizations of a Design	100%	60%	70%	60%	50%		90%			
	Automatic Low-Level Corrections	50%				50%					
	Generation of Accurate and Consistent 2D Drawings	100%	60%								
	Earlier Collaboration of Multiple Design Disciplines	100%	60%					90%			
	Easy Verification of Consistency to the Design Intent	80%		80%	60%			90%			
	Extraction of Cost Estimates during the Design Stage	85%	70%					90%			
	Improvement of Energy Efficiency and Sustainability	80%									
Construction and Fabrication Benefits	Use of Design Model as Basis for Fabricated Components	60%	70%					60%			
	Quick Reaction to Design Changes	100%	70%	90%				60%			
	Discovery of Design Errors and Omissions before Construction	80%	70%		60%			60%			
	Synchronization of Design and Construction Planning	80%	70%	70%				60%			
	Better Implementation of Lean Construction Techniques							60%			
	Synchronization of Procurement with Design & Construction	100%		70%				60%			
Post Construction Benefits	Improve Commissioning & Handover of Facility Info.	100%	80%								
	Better Management and Operation of Facilities	100%									
	Integration with Facility Operation and Management Systems	100%		80%							
	Average	88%	66%	75%	60%	50%		73%			

Table 40 BIM Benefits – Mega-projects Problems Matrix. “Ayman interview”⁵³

⁵³ Reference: own tabulation

To analysis the results out of Ayman interview, an average was calculated for the percentage of BIM benefits positive influence to each problem and it was founded that the complex nature of mega-projects got the highest positive influence by BIM benefits with 88% in average. Ayman as well kept the same concept as Salah, BIM is a coordinated data bank and its value increases with time if implemented from the early beginning of the project.

In the concept design phase, stakeholders will be sure about the future events that may happen and the connection between the existing surroundings projects and the new project, because of the feasibility and visualization abilities of BIM models. As well the BIM models made a huge advantage for MEP teams in the early design phases which improve the collaboration between the whole project disciplines.

In the detailed design phase, the automatic low-level corrections give warnings to designers about the smaller details that cannot be noticed easily, and it takes the corrective action automatically according to parameters set before by the designers. The earlier collaboration of multiple design disciplines can reach the zero clash phase before construction which is a significant saving for time and budget. For the extraction of cost estimate during the design stage depends on the quality of the BIM modeling and the level of available information.

In the construction phase, the ability to use the BIM models as bases of fabrication depends on the level of details and the quality of the modeling. The quick reaction to the design changes is an advantage, but also important to keep all participants in the project informed about all modifications "BIM clouds". Ayman refers to the advantage BIM is giving by the easy access to the information and the easy coordination between many software by IFC files, even if the project doesn't fully implement BIM. For synchronization of design and construction planning, Ayman refers to the easy information transfer from the schedule to the design, however, it is harder and time-consuming when information is transferred from the design to the schedule.

The lowest influence of BIM benefits was for fail slow and uniqueness bias, as the commitment of the project team about one scenario of the project or the project team thinking about the project as a very special project that doesn't allow them to consider the previous experience in the previous projects. Those two problems of mega-projects depend more on the project team members' personal ideas more than it depends on the technology used to implement those ideas.

Starting from the last three problems in the matrix, Ayman started to address the problems that BIM can create instead of giving the positive influence. Of course, it is a point of view to be considered, the following problems which Ayman was addressing in the last part of the interview:

- Discussions by 2D drawings can generate the risk of not include the discussed changes in the BIM models later which can create conflicts between the decisions in the meetings and the execution lead to disputes between project participants.
- In the case of High-risk delivery, using BIM can bring more details which were not visible before that. It will consume more time and may delay delivery. Referring to the concept design phase, a lower level of information is required in case of traditional design methods, however, in the case of BIM models, it needs a higher level of information and details. That will consume more time and may delay this phase because this information is not available.
- In case of inadequate budget and time, Ayman referred to the project planning as the main concept to change the situation of inadequate budget or time, not the technology. Reducing the project scope, time extension or raising the budget are decision maker solutions to overcome the situation.
- In case of misinformation, modeling can cause a lot of requirements and information should be available from the beginning, so the project team should be ready with an accurate method to collect the information needed for BIM modeling before starting.
- *“The level of information needed in the case of BIM modeling is extremely high comparing to traditional design methods” Ayman, 2018.*

5.3.3 Interviews comparison

The main purpose of this comparison between both interviews is to show the differences between owner “Salah” and contractor “Ayman” point of views about the role of BIM benefits in mega-projects. In some parts Ayman was only addressing problems without referring to the positive influence even if it exists.

- **Design (Salah “Owner” – Ayman “Contractor”)**

	BIM Benefits							
Mega-Projects Problems		Complexity of Megaprojects	Planners change	Multi Stakeholders	uniqueness bias	Fail slow	Rent seeking	Change in project scope
Design Benefits	Earlier and More Accurate Visualizations of a Design	0%	20%	10%	-20%	-10%	0%	0%
	Automatic Low-Level Corrections	10%	0%	0%	0%	-10%	0%	0%
	Generation of Accurate and Consistent 2D Drawings	-10%	30%	0%	0%	0%	0%	0%
	Earlier Collaboration of Multiple Design Disciplines	-20%	30%	0%	0%	40%	0%	0%
	Easy Verification of Consistency to the Design Intent	0%	0%	0%	-20%	40%	0%	0%
	Extraction of Cost Estimates during the Design Stage	5%	20%	0%	0%	40%	0%	0%
	Improvement of Energy Efficiency and Sustainability	10%	0%	0%	0%	0%	0%	0%

Table 41 Design Benefits interviews comparison⁵⁴

In the detailed design phase, Salah “owner” gives higher positive influence of BIM to Automatic low-level corrections, it refers to the level of accuracy the contractor needs in his own work and the lower level of trust in technology from contractor side. The extraction of cost estimates depends on the BIM model quality as Ayman “contractor”

⁵⁴ Reference: own tabulation

referred before. And the improvement of energy efficiency is usually the owner and designers main concern more than the contractor.

While Ayman as a contractor gives higher positive influence of BIM benefits to the generation of accurate 2D drawings because it is needed all the time while execution is going on "The message the designer is sending to the construction site is the drawing". As well higher positive influence on the early collaboration of multi-disciplines, because it is directly reflected in the project time and budget which are the main contract risks in most cases.

In case of project team changes, Salah gives higher positive influence for using BIM. It is related to the number of employees each organization has and naturally a construction company has a much higher number of employees comparing to the owner organization.

For uniqueness bias situation, Ayman as a contractor is giving higher positive influence to BIM benefits. Here it is related to the decision maker who can change the project scenario who is not the contractor.

For Fail slow situation, only Salah give higher positive influence to BIM benefits. It is related to the responsibility as the fail slow scenario will be due to the strategic planning for the project which is away from the contractor responsibilities and more the owner or the assigned project management team.

Extraction of cost estimates during the design phase comes as the best BIM benefit to the owner, the reason is that the owner in this phase can make many change decisions, depend on those estimates.

- **Construction (Salah “Owner” – Ayman “Contractor”)**

	BIM Benefits							
Mega-Projects Problems		Complexity of Megaprojects	Planners change	Multi Stakeholders	uniqueness bias	Fail slow	Rent seeking	Change in project scope
Construction and Fabrication Benefits	Use of Design Model as Basis for Fabricated Components	20%	20%	0%	0%	0%	0%	30%
	Quick Reaction to Design Changes	-5%	20%	0%	0%	30%	0%	30%
	Discovery of Design Errors and Omissions before Construction	15%	20%	0%	-20%	30%	0%	30%
	Synchronization of Design and Construction Planning	-10%	20%	20%	0%	30%	0%	30%
	Better Implementation of Lean Construction Techniques	0%	0%	0%	0%	0%	0%	30%
	Synchronization of Procurement with Design and Construction	-10%	0%	20%	0%	30%	0%	30%

Table 42 Construction benefits interviews comparison⁵⁵

In construction and fabrication phase, overall Salah as an Owner gives more positive influence to the BIM benefits than Ayman as a contractor. The main reason here is the trust in technology. Implementing BIM at the beginning is a client request and the whole project team follows this request. The huge risk ratio on contractors makes it difficult to trust technology to be fully implemented and build the whole decisions on the outcomes of BIM models. It is a point of view to be considered as the problems due to the individuals or the whole project team behaviour will not be changed by using BIM. Personal interference and reaction to the project strategic level still highly recommended even if when implementing BIM.

⁵⁵ Reference: own tabulation

6 . Conclusion & Future work

6.1 Conclusion

Mega-projects are huge, risky and historically connected to the financial crisis. It can make major changes to the national or even international economy, society, and politics. On the other side, BIM as the latest technology in the AEC industry offers many solutions to the common Mega-projects challenges along the project lifecycle.

The main reasons for not fully implementing BIM in Mega-projects are not related to the budget, as the cost of implementing BIM is not noticeable comparing to the huge project budget. However, Lack of owner demand for BIM, and cultural resistance and the authorization to access the project information are the main reason not to fully implement BIM in the whole project lifecycle. The major return on investment (ROI) in Airports as an example of mega-projects was reducing initial and lifecycle costs.

In concept and development design phases, “Hiding hand”, “Rent seeking” are two sides of a coin called corruption. It aims to take the decision to start non-feasible mega-projects to seek specific individuals or organizations own benefits behind this mega-projects. However BIM is offering the concept, feasibility, design benefits in this stage, but still, the consideration of the results is an individual decision which is not related to the technology. To achieve the highest benefits of BIM, it has to be implemented from the early stages of the project, therefore BIM models are working as a coordinated data storages for the huge amount of information generated through the mega-projects lifecycle. The value of this information is increasing throughout the project lifecycle.

In the detailed design phase and the initiation of the construction phase, Improvement of energy efficiency and sustainability, since the energy and MEP consultants and contractors are using the simulations abilities of BIM models to test and evaluate their scope of work in the projects even if it was not required by the client. On the other hand, generation of accurate and coordinated 2D drawings for any details within the huge amount of details in a mega-projects is a major BIM benefit, However it is creating a risky situation when changes are decided based on 2D drawings and not to be modified in BIM models, then create major problems in construction phase. Additionally, the extraction of cost estimate during any stage was a major benefit for the decision maker on the upper level of the project or even within details. Change in project scope

and the complexity of mega-projects were the most influenced problems by BIM benefits in the design phase. Although uniqueness bias and fail slow scenarios were positively influenced were the least influenced problems due to the human interference to those problems than the technology.

In the construction phase, the positive influence of BIM benefits is increasing when BIM is implemented from the early beginning of the project. The discovery of design errors before construction and the quick reaction to design changes are the most beneficial advantages BIM is offering in the early time of the construction phase. Synchronization of Design with project plan and procurement are the most beneficial advantages of BIM during the whole construction phase. The complexity of Megaprojects, satisfaction of multi-stakeholders, misinformation were the most influenced mega-projects problems in the construction phase. As a result of the maximum number of participants, the higher level of information, the booming of costs are in the construction phase. BIM can be only implemented in the construction phase only by the participants who find it beneficial to their scope of work, even if it is not the project or client requirement, likewise MEP and energy contractors.

Mega-projects participants' feedback was variant according to their positions. Owner representatives, designers, and planners tend to have a more positive image for BIM implementation in the whole project lifecycle. On the other hand, general contractors, subcontractors, and manufacturers tend to double check the outputs of BIM models and have more worries about the accuracy of inputs when it comes to the construction phase as their responsibilities are more than other participants. It is a part of the pressure added by BIM to the construction phase and a part of the traditional vs innovation culture.

When construction coming to the end and the commissioning and handover of a complex mega-project, BIM is an essential tool if implemented from the beginning of the project. The project team can access all the details and information included in the previous phases. This coordinated data storage is a treasure for the facility management team otherwise BIM will continue in operations or other systems are used in facility management. BIM models will still the source of all the details and historical data of the project.

6.2 Future work

BIM as a natural development of architects and engineers basic education in universities, which can be funded by governments and companies involved in mega-projects market as a future investment. That will reduce the gap in human resource market to acquire the talented BIM team. As well it will help to reduce cultural resistance in the AEC industry for full implementation of BIM from the early beginning of the project, not only in one part or phase. Additionally, the development of BIM organizational standard for governments or private companies will assist a smooth adoption of BIM within all projects scales and it can reduce the inputs-outputs related issues and increase the trust of BIM models results to make decisions.

Mega-projects that were constructed before the existence of BIM still need to gain the benefits of the technology. BIM for existing projects is an important research field includes facility management, renovations and demolishing as the end of the project lifecycle.

Blockchain technology can be a solution to the problem of trust within the project participants. The Blockchain allows a higher monitoring and administration of contractual documentation which cannot be performed with BIM Models. As well the access & authorization hierarchy to BIM models. Raising operational efficiency through digitizing the storage of contracts in an impenetrable manner is a huge step ahead for the construction industry. Combined with BIM Models, Blockchain is representing a very effective and promising technology for the future of the AEC industry.

Declaration of Authorship

I hereby declare that the attached Master’s thesis was completed independently and without the prohibited assistance of third parties, and that no sources or assistance were used other than those listed. All passages whose content or wording originates from another publication have been marked as such. Neither this thesis nor any variant of it has previously been submitted to an examining authority or published.

Location, Date

Signature of the student

7 . Appendixes

- **Interviews**

- ***Salah Omar Omran***

BIM Manager at Turner International Middle East, PHD Candidate, MSc, Autodesk Certified Instructor, ACP, ASA, BIM-RICS

Salah Omran has more than 12 years' experience in Building information modeling Technique. As a BIM Manager at Turner international Middle East, he led the development of the BIM implementation strategy for new Kuwait University project which One of the largest educational campuses in the world earlier with PROJACS international, he managed BIM unit in Middle East. he gained experience through working with International firms in Gulf area and successfully managing small to large projects from start to finish such as.; Arab organization to Aljazeera International-(Kuwait), BIM Management, Kuwait cancer city Hospital- Kuwait-BIM for Construction, Infectious Diseases Hospital-Kuwait -BIM for Construction, IBIS Hotels -KSA-BIM Management, NBK Data Store Building - BIM Management, Oreado Head quarter. Salah Omran holds a master's degree in Engineering & Construction Management in and now he is a PHD candidate. His last position as a Teacher assistance in the faculty of Engineering (HELWAN University-Egypt) Give him the power to be certified international trainer after holding a certificate from Autodesk to be certified Instructor.

- **Ayman Essawy**

Head of BIM Unit, Projacs International, Kuwait, RICS certified BIM Manager, Autodesk Certified Instructor.

BIM adoption is gaining speed within the Architecture, Engineering, Construction and Operations/Facility Management (AECO/FM) industry and BIM is considered a revolutionary technology and process that has quickly transformed the way buildings are conceived, designed, constructed and operated. Owners are shifting their standard practices towards the use of intelligent, parametric 3D models, which can more easily be modified, coordinated and maintained throughout the life cycle of a building. Also, BIM stands to change the role of the project management consultant as the operating system of the project changes to model-centric system, and functions that are typically performed by the Project Manager also changes.

Biography

Mr. Ayman is currently the Head of Building Information Modeling (BIM) Unit at Projacs International. He is an Autodesk certified instructor , Autodesk certified professional user , Holding a certificate in BIM Implementation and Management from the Royal Institute for Chartered Surveyors (RICS) in association with University of Salford Manchester, UK, and he has 11 years' experience of architectural design and the coordination of projects He has involved in architectural designs, projects development and coordination by using BIM software , developing and implementing the projects BIM strategy which will record key information on how BIM will be implemented and used on the project, Keep the project BIM strategy document updated over the life of the project and ensuring that all stakeholders are in alignment with the project BIM strategy throughout the Middle East with projects covering hospitals, high rise buildings, residential and commercial complexes based in Kuwait, Qatar, UAE, and Egypt.

BIM & Mega-projects Questionnaires.

Hello,

I am conducting an academic research about BIM & Mega-projects. All data will be used only for academic purposes.

*** All the questions are Multiple choice, you can use any smart device and it will take few mins.

Shortly, a Mega-project is a major project that cost more than US\$1 billion, or projects of a significant cost that attract a high level of public attention or political interest because of substantial direct and indirect impacts on the community, environment, and budgets.

\$500 million project in a medium-sized town may be considered "mega" as it depends about the importance of the project to the stakeholders and the impact to community.

The targeted group is all individuals involved in AEC industry with Mega-projects experience.

Glossary:

BIM: Building Information modeling

AEC: Architecture, Engineering, construction

Definitions

* Uniqueness bias: is here defined as the tendency of planners and managers to see their projects as singular. This particular bias stems from the fact that new projects often use non-standard technologies and designs, leading managers to think their project is more different from other projects than it actually is. Uniqueness bias impedes managers' learning, because they think they have nothing to learn from other projects as their own project is unique. This lack of learning may explain why managers who see their projects as unique perform significantly worse than other managers. Project managers who think their project is unique are therefore a liability for their project and organization. For mega-projects this would be a mega-liability.

** Fail slow: Frequently there is over-commitment to a certain project concept at an early stage, resulting in "lock-in" or "capture," leaving alternatives analysis weak or absent, and leading to escalated commitment in later stages.

Thank you for your time and appreciated support

For any comments please contact me by Email

mkh244@hotmail.com

Best Regards

Mohamed

* Required

Organization Questions

1. **1. What role do you preform currently within your organization? ***

2. **2. How many years of experience in AEC industry do you have? ***

Mark only one oval.

- 1 to 5 years
- 5 to 10 years
- 10 to 20 years
- more than 20 years

3. How many years of experience with BIM do you have? **Mark only one oval.*

- No experience
- 1 to 5 years
- 5 to 10 years
- more than 10 years
- Other: _____

4. In which country/region does your organization carry out projects? **Check all that apply.*

- Africa
- Americas
- Asia
- Australia
- Europe
- Other: _____

5. What is the major sector of your organization projects? **Check all that apply.*

- Infrastructure
- Residential and Touristic
- High rise Buildings
- Transportation
- Industrial
- Other: _____

6. What is the average project range your organization is involved? **Mark only one oval.*

- Less than 1 Million USD
- 1 to 10 Million USD
- 10 to 100 Million USD
- More than 100 Million USD
- More than 1 Billion USD
- Other: _____

7. Does your organization currently use BIM? **Mark only one oval.*

- Yes
- No

8. If No, What is your organization plan to use BIM? Please comment below

9. 7. If yes, How many years has your organization been using BIM?*Mark only one oval.*

- less than 1 year
- 1 to 3 years
- 3 to 5 years
- more than 5 years
- more than 10 years

10. 9. What is your organization position in the project? **Mark only one oval.*

- Client "Owner" *Skip to question 11.*
- Consultant *Skip to question 18.*
- Contractor *Skip to question 27.*
- Owner Rep. "Facility Manager" "Operators" *Skip to question 36.*

For Owners: How far do you agree with the following statements?**11. 1. For Owners of Complex Mega-projects ****Mark only one oval per row.*

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary for Concept, Feasibility, Design Benefits	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Increase Building Process Performance and Quality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary for Improving Collaboration Using Integrated Project Delivery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

12. 2. For Owners, In case of Project Team changes in Mega-projects **Mark only one oval per row.*

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary for Concept, Feasibility, Design Benefits	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Increase Building Process Performance and Quality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary for Improving Collaboration Using Integrated Project Delivery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

13. 3. For Owners, In case of Multi Stakeholders in Mega-projects **Mark only one oval per row.*

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary for Concept, Feasibility, Design Benefits	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary for Improving Collaboration Using Integrated Project Delivery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

14. 4. For Owners, Fail slow: Frequently there is over-commitment to a certain project concept at an early stage, resulting in "lock-in" leaving alternatives analysis weak or absent, and leading to escalated commitment in later stages. **Mark only one oval per row.*

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary for Concept, Feasibility, Design Benefits	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

15. 5. For Owners, In case of Project Scope Changes in Mega-projects **Mark only one oval per row.*

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary for Concept, Feasibility, Design Benefits	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Increase Building Process Performance and Quality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary for Improving Collaboration Using Integrated Project Delivery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

16. 6. For Owners, In case of High Risk Delivery in Mega-projects **Mark only one oval per row.*

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to Increase Building Process Performance and Quality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary for Improving Collaboration Using Integrated Project Delivery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

17. 7. For Owners, In case of misinformation in Mega-projects **Mark only one oval per row.*

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary for Concept, Feasibility, Design Benefits	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary for Increasing Building Performance and Quality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary for Improving Collaboration Using Integrated Project Delivery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

For Designers "Planners" : How far do you agree with the following statements?

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18. 1. For Designers of Complex Mega-projects *

Mark only one oval per row.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to Earlier and More Accurate Visualizations of a Design	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Automatic Low-Level Corrections	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Generation of Accurate and Consistent 2D Drawings	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Earlier Collaboration of Multiple Design Disciplines	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Easy Verification of Consistency to the Design Intent	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Extraction of Cost Estimates during the Design Stage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Improvement of Energy Efficiency and Sustainability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

19. 2. For Designers, In case of Project team changes in Mega-projects *

Mark only one oval per row.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to Earlier and More Accurate Visualizations of a Design	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Generation of Accurate and Consistent 2D Drawings	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Earlier Collaboration of Multiple Design Disciplines	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Extraction of Cost Estimates during the Design Stage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

20. 3. For Designers, In case of Multi Stakeholders in Mega-projects *

Mark only one oval per row.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to Earlier and More Accurate Visualizations of a Design	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Easy Verification of Consistency to the Design Intent	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

21. 4. For Designers, Uniqueness Bias: the tendency of planners and managers to see their projects as singular. * 140

Mark only one oval per row.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to Earlier and More Accurate Visualizations of a Design	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Easy Verification of Consistency to the Design Intent	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

22. 5. For Designers, Fail slow: Frequently there is over-commitment to a certain project concept at an early stage, resulting in "lock-in" or "capture," leaving alternatives analysis weak or absent, and leading to escalated commitment in later stages. *

Mark only one oval per row.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to Earlier and More Accurate Visualizations of a Design	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Automatic Low-Level Corrections	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Earlier Collaboration of Multiple Design Disciplines	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Easy Verification of Consistency to the Design Intent	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Extraction of Cost Estimates during the Design Stage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

23. 6. For Designers, In case of Project Scope change in Mega-projects *

Mark only one oval per row.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to Earlier and More Accurate Visualizations of a Design	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Earlier Collaboration of Multiple Design Disciplines	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Easy Verification of Consistency to the Design Intent	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Extraction of Cost Estimates during the Design Stage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

24. 7. For Designers, In case of High Risk Delivery in Mega-projects *

Mark only one oval per row.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to Earlier and More Accurate Visualizations of a Design	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Automatic Low-Level Corrections	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

25. 8. For Designers, In case of Budget and Time are inadequate in Mega-projects *

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Mark only one oval per row.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to Earlier and More Accurate Visualizations of a Design	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Easy Verification of Consistency to the Design Intent	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Extraction of Cost Estimates during the Design Stage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

26. 9. For Designers, In case of misinformation in Mega-projects **Mark only one oval per row.*

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to Earlier and More Accurate Visualizations of a Design	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Easy Verification of Consistency to the Design Intent	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Extraction of Cost Estimates during the Design Stage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

For Contractors & Manufacturers: How far do you agree with the following statements?**27. 1. For Contractors of Complex Mega-projects ****Mark only one oval per row.*

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to the Use of Design Model as Basis for Fabricated Components	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Quick Reaction to Design Changes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Discovery of Design Errors and Omissions before Construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Synchronization of Design and Construction Planning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Better Implementation of Lean Construction Techniques	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Synchronization of Procurement with Design and Construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

28. 2. For Contractors, In case of Project team changes in Mega-projects **Mark only one oval per row.*

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to the Use of Design Model as Basis for Fabricated Components	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Quick Reaction to Design Changes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Discovery of Design Errors and Omissions before Construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Synchronization of Design and Construction Planning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

29. 3. For Contractors, In case of Multi Stakeholders in Mega-projects **Mark only one oval per row.*

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to Quick Reaction to Design Changes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Synchronization of Design and Construction Planning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Synchronization of Procurement with Design and Construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

30. 4. For Contractors, Uniqueness Bias: as the tendency of planners and managers to see their projects as singular. **Mark only one oval per row.*

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to Discovery of Design Errors and Omissions before Construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

31. 5. For Contractors, Fail slow: Frequently there is over-commitment to a certain project concept at an early stage, resulting in "lock-in" or "capture," leaving alternatives analysis weak or absent, and leading to escalated commitment in later stages. **Mark only one oval per row.*

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to Quick Reaction to Design Changes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Discovery of Design Errors and Omissions before Construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Synchronization of Design and Construction Planning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Synchronization of Procurement with Design and Construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

32. 6. For Contractors, In case of Project scope changes in Mega-projects **Mark only one oval per row.*

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to the Use of Design Model as Basis for Fabricated Components	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Quick Reaction to Design Changes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Discovery of Design Errors and Omissions before Construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Synchronization of Design and Construction Planning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Synchronization of Procurement with Design and Construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

33. 7. For Contractors, In case of High Risk Delivery in Mega-projects **Mark only one oval per row.*

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to the Use of Design Model as Basis for Fabricated Components	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Quick Reaction to Design Changes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Discovery of Design Errors and Omissions before Construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Synchronization of Design and Construction Planning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Synchronization of Procurement with Design and Construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

34. 8. For Contractors, In case of Budget and Time are inadequate in Mega-projects **Mark only one oval per row.*

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to the Use of Design Model as Basis for Fabricated Components	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Quick Reaction to Design Changes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Discovery of Design Errors and Omissions before Construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Synchronization of Design and Construction Planning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Synchronization of Procurement with Design and Construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

35. 9. For Contractors, In case of Misinformation in Mega-projects *

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Mark only one oval per row.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to the Use of Design Model as Basis for Fabricated Components	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Quick Reaction to Design Changes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Discovery of Design Errors and Omissions before Construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Synchronization of Design and Construction Planning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Synchronization of Procurement with Design and Construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Post Construction Benefits: How far do you agree with the following statements?

For Owners, Facility Managers, Operations, Service Suppliers

36. 1. Post Construction Benefits in Complex Mega-projects **Mark only one oval per row.*

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to Improved Commissioning and Handover of Facility Information	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Better Management and Operation of Facilities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Integration with Facility Operation and Management Systems	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

37. 2. Post Construction Benefits, In case of Project team changes in Mega-projects **Mark only one oval per row.*

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to Improved Commissioning and Handover of Facility Information	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Better Management and Operation of Facilities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Integration with Facility Operation and Management Systems	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

38. 3. Post Construction Benefits, In case of Multi Stakeholders in Mega-projects *

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Mark only one oval per row.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to Improved Commissioning and Handover of Facility Information	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Better Management and Operation of Facilities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Integration with Facility Operation and Management Systems	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

39. 4. Post Construction Benefits, In case of Misinformation in Mega-projects. **Mark only one oval per row.*

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM is necessary to Improved Commissioning and Handover of Facility Information	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Better Management and Operation of Facilities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM is necessary to Integration with Facility Operation and Management Systems	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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