The Impact of the BIM Organizational Risks on the BIM Enhanced Project Delivery and Organization Improvement

أثر المخاطرالتنفيذية لتقنية نمذجة معلومات المباني (BIM) على قدرتها على تحسين إنتاج المشاريع وتطوير المؤسسات في مجال الهندسة والبناء

by

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A dissertation submitted in fulfilment of the requirements for the degree of MSc PROJECT MANAGEMENT at The British University in Dubai

October 2017

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Abstract:

This dissertation paper targets the topic of the Building Information Modelling (BIM) due to its importance in enhancing the delivery of construction projects as well as the challenges that face its implementation and jeopardize its advantages, it attempts to provide a brief background about BIM and its main differences with the traditional CAD method, then it discusses the topic of risk in general and moves on to explain the main types of BIM challenges that were suggested in the literature.

Furthermore, this research paper uses a number of project case studies reported by other researchers to address the relationship between the risks of BIM and three of the main advantages that it offers to projects and organizations including the reduction of cost and time and the improvement of collaboration, the paper then proposes the main research hypothesis which assumes that the perceptions of the impact of BIM challenges on its advantages are dependent on the demographic attributes of industry professionals, this includes aspects such as the type and size of the organization, the role and the general and BIM experience levels. This proposition is then tested through a questionnaire that first establishes the earlier mentioned demographic characters of the respondents and then it examines how respondents would rate the effect of 18 BIM risks on the three major BIM advantages of cost, time and collaboration. In addition to the survey, an interview with a senior products manager in a major engineering consultancy has been conducted to further elaborate on the challenges of BIM and the possible strategies for managing them.

The main outcomes of the questionnaire are first presented in a descriptive manner by explaining the demographic distributions of the sample and how they might impact the ranking of BIM risks, then a frequency analysis studies the rating patterns and distributions of certain BIM risks that were either agreed or disagreed on by the majority of the respondents, after that rankings of the BIM challenges based on their impact on its advantages and according to the demographic groups of the respondents are explained. Moreover, a variance analysis of the ratings of BIM risks based on the demographic attributes of the respondents is conducted through an SPSS program; its findings either prove or reject the research hypothesis. Then a factor analysis is produced in the same program to group the 18 BIM risks into a smaller number of components. Finally, the discussion of this paper tries to find a relationship between the findings in the literature, the survey and the interview regarding the risks of BIM and their effect on its major advantages and suggests certain areas for future investigation.

ملخص البحث:

يهدف هذا البحث إلى تقديم موضوع نمذجة معلومات المباني (BIM) بسبب أهميتها ودورها في تحسين الإنتاج في مشاريع الهندسة والبناء وأيضاً بسبب المشاكل التي تواجه تطبيقها وتعرّض فوائدها للخطر. يبدأ البحث بإعطاء خلفية عن ال (BIM) وأهم الفوارق بينها وبين الطريقة التقليدية المعروفة بال (CAD) ، بعد ذلك يتم مناقشة موضوع المخاطر في إدارة المشاريع بشكل عام ومن ثم يتم عرض أهم أنواع المخاطر التي تواجه ال (BIM) كما تم طرحها من قبل باحثين آخرين.

يقوم هذا البحث بعد ذلك باستخدام أمثلة لمشاريع مطروحة في عدة بحوث ومقالات من أجل درس العلاقة بين مخاطر ال (BIM) وثلاثة من أهم فوائدها وهم: تقليلة الميزانية، تقصير المدة وتحسين عملية التنسيق في مشاريع الهندسة والبناء. فيما بعد، يتم طرح نظرية البحث التي تفترض بأن النظرة إلى تأثير مخاطر ال (BIM) على فوائدها تعتمد على الخواص المهنية للمحترفين في مجال الهندسة والبناء مثل نوع وحجم الشركة، المنصب، الخبرة الإحترافية والخبرة في مجال ال (BIM). هذه النظرية يتم اختبارها من خلال استبيان يكتشف الخواص المهنية التي تم ذكرها لعدد من المحترفين في مجال الهندسة والبناء ومن ثم يدرس تقييمهم لأثر مخاطر ال (BIM) على فوائدها. بالإضافة إلى الاستبيان، تم إجراء مقابلة مع مدير المنتجات في شركة استشارات هندسية كبيرة من أجل التعمق في مخاطر ال (BIM) وأهم الطرق التي تساعد على التغلب عليها.

فيما بعد، يعرض هذا البحث نتائج الاستبيان بشكل وصفي من خلال شرح توزيع العينة حسب الخواص المهنية للمستجيبين وكيف يمكن أن يؤثر هذا التوزيع على تصنيف مخاطر ال (BIM) . بعد ذلك يتم تحليل توزيع الردود وكيفية تكرارها لبعض مخاطر ال (BIM) التي وافق أو اختلف عليها أغلبية المستجيبين، ثم يتم شرح نتائج تصنيف مخاطر ال (BIM)حسب تأثيرها على كل من فوائدها الثلاث التي سبق ذكرها وأيضاً حسب الخواص المهنية للمستجيبين.

يُجري هذا البحث من بعد ذلك اختباراً من أجل التحقق من أي اختلافات بين ردود المستجيبين حسب خلفياتهم المهنية من خلال برنامج (SPSS) ، نتائج هذا الاختبار تقوم إمّا بإثبات أو رفض نظرية البحث المقترحة سابقاً. يتم أيضاً إجراء اختبار في نفس البرنامج من أجل تقليل عدد مخاطر ال (BIM) الثمانية عشر في الاستبيان من خلال احتوائهم في عدد أقل من المجموعات.

أخيراً، تتم مناقشة جميع المعلومات السابقة عن أثر مخاطر ال (BIM) على فوائدها من أجل البحث عن علاقة بين النظريات والأمثلة في البحوث السابقة ونتائج الاستبيان بالإضافة إلى المقترحات في المقابلة، يتم أيضاً تقديم بعض العناوين المقترحة من أجل بحوث مستقبلية.

Acknowledgements:

After god's help and guidance, the assistance of Professor Dr. Halim Boussabaine throughout the course of this paper played a vital role in its completion, his support and direction made it possible for this paper to be fully focused on the objectives that were set within the time constraints.

My appreciation also goes to Dr. Khalid Al Marri, instructor at the British University in Dubai for his help in previous assignments that led to the composition of this paper; I must also not forget the university staff who gave it their all to assist in completing the journey of this Master's program. I would like to state my gratefulness to my employer as well for being fully understanding and supportive of the continuation of my studies.

Last but not the least, I would like to thank my family; my mother and father along with my five siblings who gave me all the emotional care and encouragement that helped ease the stressful times during my examinations and submissions.

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CHAPTER 1: INTRODUCTION:

1.1 Chapter Introduction:

The first chapter in this research paper introduces the topic of Building Information Modeling, it identifies the reasons behind writing this paper by explaining the importance of BIM and the risks that face its implementation, it states the problem, questions and goals of this research as well as the main research hypothesis, after that it defines the scope and focus of the paper and the structure of the research through the chapters that it contains.

1.2 Background, Existing Gap and Research Rationale:

The world of Architecture, Engineering and Construction (AEC) has gone through a ground-breaking journey of developments and advancements in the last few decades, the United Arab Emirates and the Emirate of Dubai specifically have seen an even bigger and faster journey considering the starting phase of this process more than 20 years ago as well as the harsh climate conditions that can act against such innovation. In spite of the numerous technologies, databases and skills discovered in the industry worldwide; there has constantly been a drive towards enhancing the effectiveness of the design and construction processes through minimizing the time and resources needed to reach project objectives. As a result of this ambition, a new technology has been developing and growing in the past few years with a pace that has never been witnessed before; the Building Information Modelling (BIM) is a technology-based process that originates from the concept of collaborating and combining several engineering design inputs into one single entity that contains all the information required to fully construct and maintain a facility. The creation of BIM has opened an endless range of opportunities which are represented by added design dimensions (cost estimation and project scheduling) ultimately resulting in reduced budgets and less project durations not to mention its role in better documentation of the project information which leads to more efficient realization of the project goals and a solid database for future projects. The challenges that face the BIM technology and the absence of global initiatives to take leadership in the process of improving the efficiency and maximizing the benefits of BIM are somewhat considered a gap in the AEC industry, those areas have been addressed by many researchers but little practical work has been done so far. The rationale of this study lies entirely behind the importance of BIM and the major enhancements that it can provide to the design and construction processes. It has been widely debated that the BIM technology is considered as the main prospect for the Architecture, Engineering and Construction Industry (Thomassen, 2011). The lack of awareness about the benefits of BIM and the way it works due to its relatively new emergence and the difficulty of the current process in adapting to it creates a strong drive towards addressing the BIM challenges and finding strategies to mitigate them.

1.3 Problem Statement:

As is the case with all emerging processes and technologies, the BIM technology is still lacking in many areas and has a number of drawbacks that can put its great benefits and opportunities in danger. One of the most notable challenges that stand in the way of implementing BIM is the major change that organizations have to perform in their organizational structure, as BIM impacts the way that businesses operate entirely, organizations have to alter their policies and strategies to be aligned with the concept of BIM. Another significant challenge for BIM is the large initial investment costs represented by the costs of training and recruitment, upgrading computers to handle the requirements of BIM, software licenses and technical support. On the contractual level, BIM faces certain risks when it comes to its collaborative nature which is new to all stakeholders, BIM's introduction of new roles and responsibilities for each party involved in the project as well as the lack of specific BIM contracts both create more risk sharing between the stakeholders. BIM lacks in the technical aspects as well, the incompatibility between BIM programs is considered as one of the biggest threats to the improved documentation and digitalized databases that BIM offers as in many cases valuable data is lost in the transfer process.

1.4 Research Questions and Hypothesis:

The two main questions that this paper attempts to answer are:

1- **What are the Building Information Modeling challenges with the highest impact on its Cost Reduction, Time Reduction and Collaboration Improvement advantages?**

2- **Is there a difference in the perceptions of industry professionals based on their career backgrounds when it comes to the impact of BIM risks on its advantages?**

The proposed research hypothesis and null hypothesis are shown below in ***Figure-1***.

H_0: Null Hypothesis – There is no significant difference between the industry professionals' ratings of the impact of BIM risks on its advantages based on their career backgrounds.

H_1: Research Hypothesis – There is a significant difference between the industry professionals' ratings of the impact of BIM risks on its advantages based on their career backgrounds.

Figure 1: Main Research and Null Hypotheses (Source: Researcher)

1.5 Research Aims and Objectives:

This research intends to explain the concept of BIM and its biggest advantages compared to the traditional CAD method, it highlights the major enhancements that BIM provides to the project delivery which act as the success criteria of BIM projects, it studies specific barriers that obstruct the adoption of BIM in the AEC industry and most importantly, it uses a questionnaire to examine the effects that BIM challenges have on the enhanced features created by BIM and whether the understanding of these effects is dependent on the demographic characteristics of industry professionals, finally the study introduces an interview with an experienced BIM professional to suggests a number of solutions and strategies to help in the adoption of BIM.

The main objectives of this study are:

1- To explain the notion of BIM and its advantages compared to the CAD method.
2- To define the main advantages that BIM brings to projects and organizations.
3- To identify the main organizational challenges of BIM.
4- To investigate the impact of BIM challenges on its advantages.
5- To determine any variance in industry perceptions of the impact of BIM risks on its advantages based on professional backgrounds.
6- To propose strategies for mitigating and reducing the effects of BIM challenges.

1.6 Research Scope:

The key emphasis of this paper is on the process and organizational challenges of the BIM technology, those risks are concerned with the managerial barriers that face organizations internally as they plan to incorporate BIM, this paper does not study in full depth the challenges associated with the legal and contractual sides of BIM nor does it examine the detailed technical aspects of the BIM programs, it does however discuss the legal and technical challenges that have a major impact on the organizational sides of the implementation process. This study also focuses on the impact of BIM challenges only on three of its benefits: cost and time reduction and collaboration improvement.

1.7 Research Structure:

The structure of the research shall be as follows:

Chapter 1 **(Introduction):** this chapter starts by giving a brief background about BIM and its association with the AEC industry, it then argues the reasons behind conducting this research with the existing gap between the challenges of BIM and the realization of its benefits, it states the research problem, questions and main hypothesis, then it clarifies the main goals and objectives of this research, after that it mentions the main focus of the study and what is excluded from its scope, finally it briefly explains the structure of the research and the main contents of each chapter.

Chapter 2 **(Advantages of BIM):** this chapter starts by describing the idea of BIM and where it came from, it then explains the main added features that BIM has over the traditional CAD technology, after that it examines the primary advantages of BIM represented by its major enhancements to projects and organizations, finally the chapter focuses on three of those advantages and gives project examples to support them.

Chapter 3 **(Risks of BIM):** this chapter attempts to explain the concept of risk and risk management in project management, then it investigates the types of risks that face the BIM application and provides more details on the risks associated with the technology, process and policy fields of BIM.

Chapter 4 **(Conceptual Model):** this chapter demonstrates BIM project case studies with challenges that affected its three advantages mentioned earlier, it then adds the literature findings from Chapters 2 & 3 to find a link between the BIM risks and key advantages, finally it suggests a conceptual framework around the research hypothesis.

Chapter 5 **(Research Methodology):** this chapter clarifies the methods used in collecting and analyzing data to test the suggested hypotheses, it explains the sample selected for the survey, the structure of its questions, the dependent and independent variables, the coding of the survey parameters and the analysis tests that will be used in the SPSS software for hypothesis testing. Finally, this chapter briefly describes how an interview with a senior products manager was conducted to contribute to the research.

Chapter 6 (Descriptive Analysis): this chapter investigates the descriptive findings from the survey starting with the demographic distributions of the sample based on the type and size of organization, position and general and BIM expertise, then it discusses the reliability of the survey results through the values of Cronbach's Alpha, it analyzes the types of confident and unconfident rating frequencies for the impact of BIM risks on its advantages and finally it describes the ranking of BIM challenges based on their impact on its three benefits and based on the demographic groups of the respondents.

Chapter 7 (BIM Risks Variance Analysis): this chapter uses two variance tests (independent t-test and one-way ANOVA) to determine any difference in respondents' ratings of the impact of BIM risks on its advantages based on their career backgrounds.

Chapter 8 (BIM Risks Factor Analysis): this chapter conducts a factor reduction process in order to minimize the number of BIM risks used in the survey; it uses a rotated component matrix to put the risks in common latent groups.

Chapter 9 (Discussion, Conclusions & Recommendations): the final chapter summarizes all the information explained in the study and tries to link the findings from the literature, the survey and the interview, it offers a number of recommendations from the interview for mitigating the BIM challenges, then it explains the implications of this paper on the BIM research field, its main limitations and a few areas for future studies.

1.8 Chapter Conclusion:

This chapter has explained the rationale behind the research through the importance of BIM and the resulting risks of its adoption; it also stated the research problem of how those risks can jeopardize BIM's major benefits to projects and organizations, it proposed two research questions where one seeks to determine the BIM risks with the highest impact on three of its advantages and the other attempts to find out whether the perceptions of this impact differ among construction professionals. The research hypothesis assumes a difference in the ratings of this impact based on respondents' professional backgrounds. The main objectives of this paper are explained as well as the scope of the research and the structure of its chapters.

CHAPTER 2: ADVANTAGES OF BIM:

2.1 Chapter Introduction:

The second chapter of this research explains the theory behind the Building Information Modeling, it describes how it emerged and developed throughout the years, then it illustrates how BIM has numerous benefits over the traditional CAD method, after that it clarifies the major advantages that BIM brings to projects and organizations and finally it elaborates on three of those advantages as the main focus of this research.

2.2 The Definition and Emergence of BIM:

The idea behind the Building Information Technology dates back to the 1960s after Douglas Englebart, an American engineer & inventor explained the concept of creating inputs of actual building information like sizes, materials and specifications into a program, this allows for studying and controlling the created integrated model which represents the full form that the facility will reach once constructed (Quirk, 2012). From that time, several definitions have been assigned to the BIM technology but the best known one has been given by The US National Building Information Model Standard Project Committee as: "*A digital representation of physical and functional characteristics of a facility*". (National Institute of Building Sciences 2012, p.338). The NBIMS committee also argued that BIM is an approach of shared data that produces a concrete base for creating decisions over the lifecycle of the facility. Figure-2 below explains the main principle of BIM.

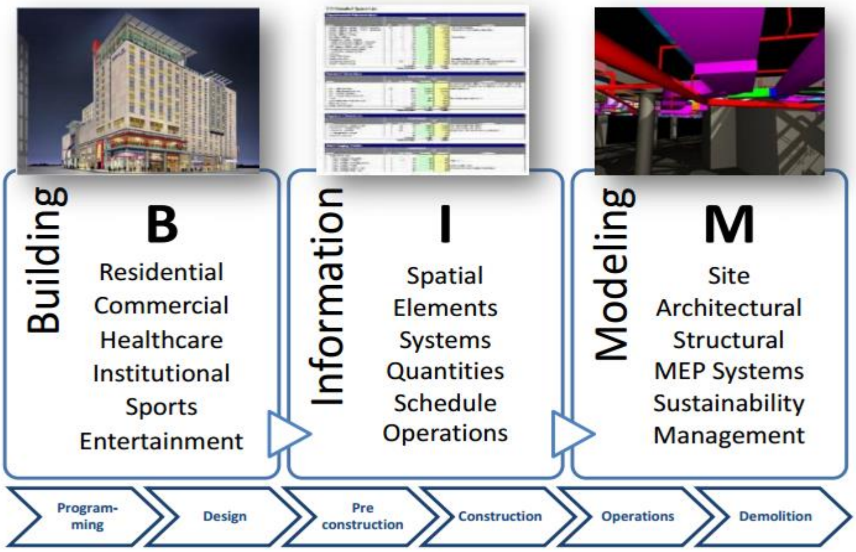


Figure 2: The concept of BIM (Azhar, Khalfan and Maqsood 2012, p.16)

2.3 BIM Application vs. Traditional Application (CAD):

The establishment of the BIM technology has introduced many advantages over the traditional CAD (computer-aided design) process; those advantages differ based on the stages of the project's lifecycle. Some of the most notable advantages that BIM offers compared to CAD include the integration and improvement of the project documentation, enhanced model visualization, detection of clashes and errors, estimating costs and several others (Azhar, 2011).

It has been argued that the AEC industry has minimized the risks in construction projects and reduced the overall budgets of projects by incorporating BIM, it has also reduced the number of variation orders and information requests which ultimately resulted in better decision-making (Jones, 2014). One of the significant added features of BIM is its ability to control the design early in the project, this means that instead of the traditional design-to-build method, BIM uses a build-to-design process which mainly depends on a precise simulation of the final model that will be erected. Hergunsel (2011) desribes the build-to-design method of BIM in ***figure-3***, he claims that this method integrates all the final design aspects of the model in the early stages of the project allowing for more accurate consideration of all the technical and visual requirements of the facility.

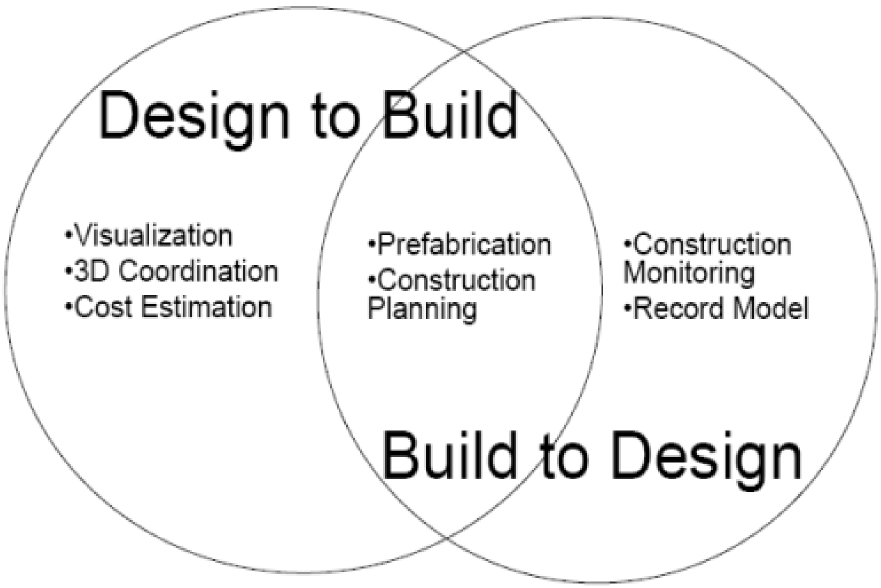


Figure 3: Design to Build and Build to Design Diagram in BIM (Hergunsel 2011, p.62)

Documentation Efficiency: the collaboration method that BIM uses helps in improving the documentation value when compared to the typical design-bid-build method, the typical process usually experiences a discontinuation of the documentation value after the construction stage where during the operation and maintenance of the facility a different party will be in charge of the management of the facility and a database is created for the operational purposes resulting in a decrease of the documentation value, while in the BIM process the integration of the operational requirements of the facility from the project start leads to sustaining a better value for the project documents (Eastman et al. 2011).

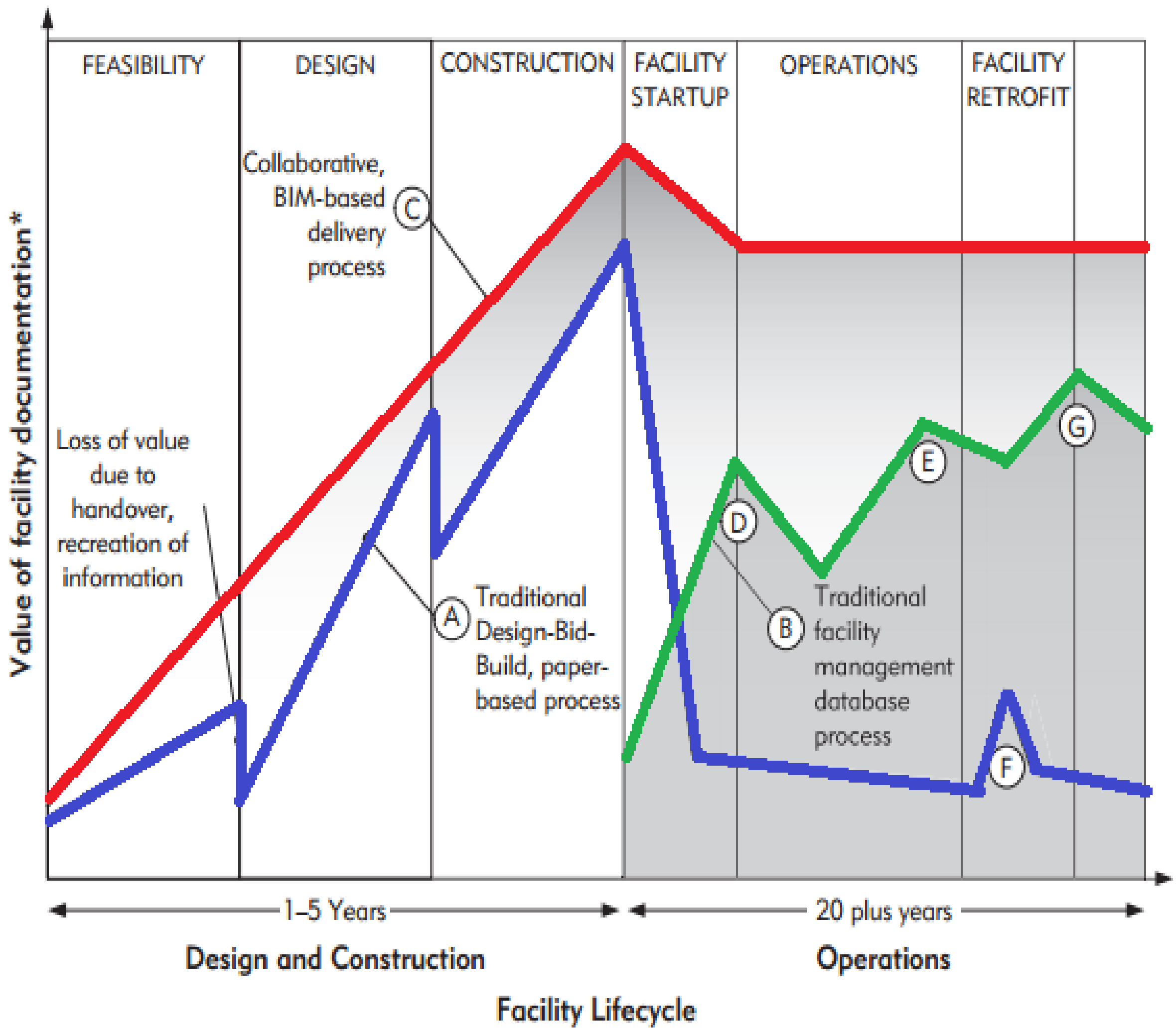


Figure 4: Traditional single-stage drawing-based deliverables and traditional facility management database vs. BIM based deliverables throughout the project delivery/operation. (Adapted from Eastman et al. 2011, p.95)

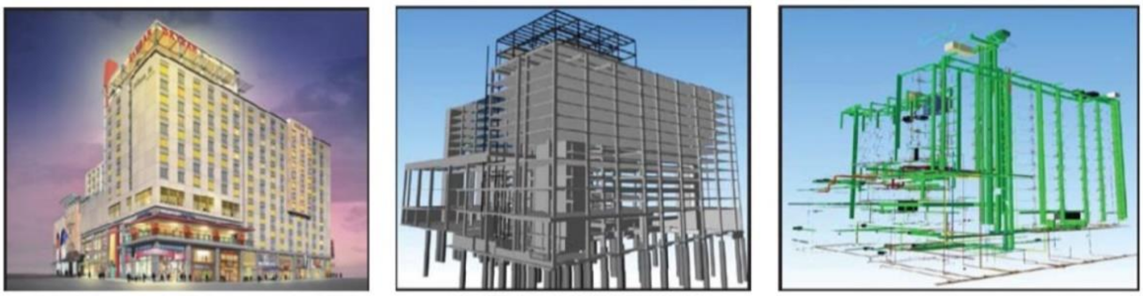
Some of the main advantages of BIM over CAD are:

A- *Model Visualization:*

The BIM application allows for visualizing and having a better perspective of the building for all design disciplines, the use of accurate data inputs of the building specifications gives the ability of imitating a fully-constructed model through an electronic version; this in turn results in having a better idea about the project advancement and the final product (Abdelhady, 2013). On the contrary, the traditional CAD process is based on segregated 2D and 3D drawings and documents that lack integration and that are produced manually rather than on the basis of real building data.

B- *Coordinated Documents and Change Control:*

It has been claimed that the model-based coordination that includes both documents and installations is considered as the key focus of the BIM application and its main point of takeoff (Hardin and McCool, 2015). The 3D/4D technologies used by BIM assist in creating documents that are entirely integrated between the different design inputs including architectural, sustainable, structural, electrical and mechanical designs (Abdelhady, 2013). On the other hand, the traditional CAD application requires constant follow-up and manual update of any design change resulting in many more variations, longer project durations and larger amounts of resources.



(a) Architectural Model (b) Structural Model (c) Plumbing Model

Figure 5: Building Information Modeling for Hilton Aquarium, Atlanta, Georgia, USA (Azhar 2011, p.6)

C- *Error/Clash Detection:*

It has been debated that BIM's ability to detect conflicts between several design elements such as architectural walls, structural beams, plumping pipes and many other has helped in reducing contract values and project schedules. The CAD process however does not have a common interface between different design platforms which makes it much harder to detect clashes and errors (Azhar, 2011).

D- *Schedule Planning (4D):*

BIM's ability to simulate and analyze the sequencing of construction activities of a project has resulted in numerous time savings in construction projects. Simeone et al. (2013) argue that 4D BIM is a smart method of associating building components to a time/schedule dimension. Moreover, Azhar (2011) claims that the use of BIM has resulted in project schedule reductions based on 32 BIM case studies.

E- *Cost Estimation (5D):*

The precise building information inputs offered by BIM allows for fully detailed cost estimating and quantity takeoffs based on the specifications of equipment, materials and finishes. Azhar (2011) argues that the added 5D feature (cost estimation) of BIM has allowed for great cost savings as well as the reduction of the time required to manually estimate costs which is usually used in the traditional CAD method.

F- *Facility Management (6D):*

The role of BIM in increasing the efficiency of building documents which has been explained earlier allows for large enhancements of the process of managing a facility after its construction. Akcamete, Akinci and Garrett (2010) state that the role that facility managers play on a project can affect up to 60% of the total project cost. Furthermore, Davtalaba and Delgadob (2014) found from a project case study that BIM's 6D has resulted in 80% decrease in the total time for maintenance/operations.

2.4 Main Advantages of BIM:

The creation of the Building Information Modelling (BIM) technology and its utilization in construction projects has given many measurable benefits to both projects and organizations, BIM's impact on projects has been evident through the enhanced overall delivery of project products and its impact on organizations has been identified as continuous improvement and development of the business processes and knowledge accumulation inside the company on the long run. Bryde, Broquetas and Volm (2013) argue that the performance of BIM projects can be measured using certain success factors for construction projects that were derived from the Project Management Body of Knowledge (PMBOK) created by the Project Management Institute (PMI), those success factors consist of nine major areas of success that project managers are expected to deliver, they are illustrated in ***figure-6***.

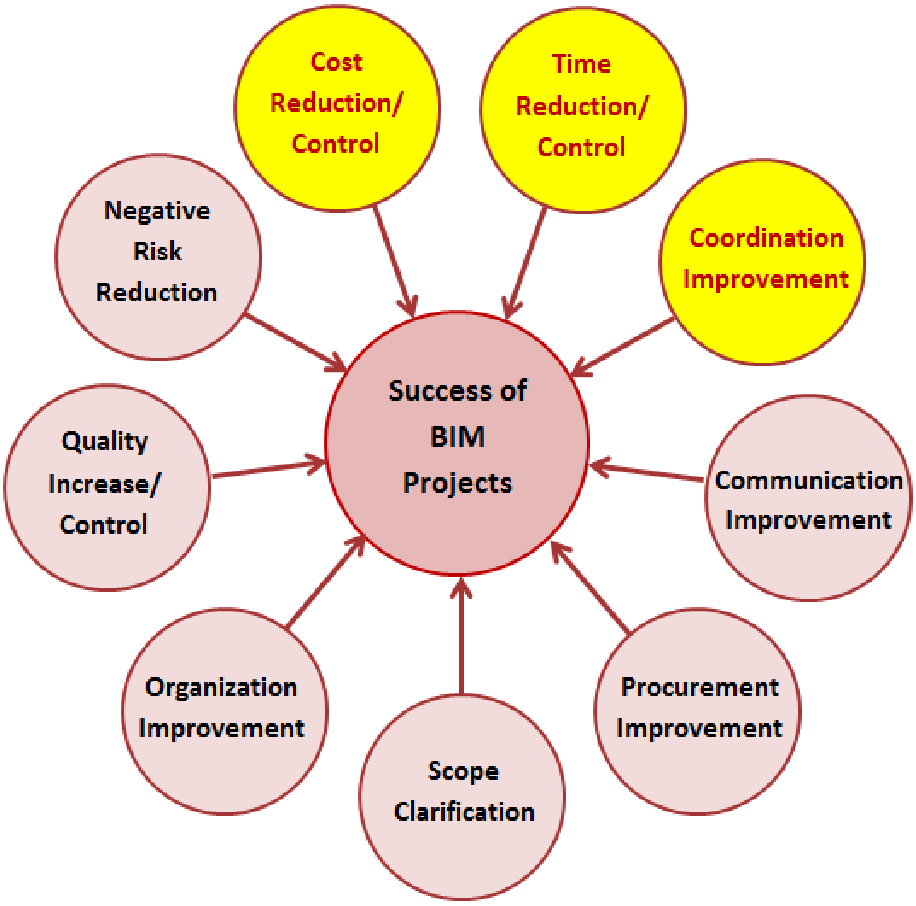


Figure 6: **Success Factors of BIM Projects (Selected ones in yellow)** (Adapted from Bryde, Broquetas and Volm 2013, p.974)

In conjunction with the success factors mentioned by Bryde, Broquetas and Volm (2013), Arayici et al. (2011) have conducted an investigation to find the key performance indicators and success factors of BIM implementation in an architectural firm in the UK, the main factors included: (project man hours, development rate, income per head, IT investment per income, liquidity of assets (cash flow), improved overall architecture, enhanced final products, minimized soft project costs (printing, document shipment and travel expenses), percentage of won bids, fulfillment of owner needs and improvement of staff skills and information growth). These 11 key performance indicators for BIM projects can be grouped into six categories similar to the ones depicted by Bryde, Broquetas and Volm (2013), these categories are: (**cost reduction**: man hours, income, IT investment, cash flow and reduced soft costs), (**time reduction**: development rate), (**quality improvement**: enhanced products), (**organization improvement**: enhanced architecture, staff skills and overall knowledge), (**negative risk reduction**: percentage of won bids) and (**stakeholder collaboration improvement**: client satisfaction).

2.5 Selected Advantages of BIM:

According to a study by Eadie et al. (2013) which examined the most important KPIs for BIM projects in the eyes of 92 industry professionals, the top three metrics were overall budget, cost of changes and program duration. On the other hand, Omar (2015) and Mehran (2016) both found in studies examining BIM adoption in the UAE that BIM's collaboration and communication improvement received the highest rating among all other BIM advantages investigated. As a result of the above mentioned papers as well as the studies conducted by Arayici et al. (2011) and Bryde, Broquetas and Volm (2013), three BIM advantages have been selected for further investigation on the way they can be measured in BIM projects as well as the study of the impact of BIM risks on those success factors which will be presented in ***Section 4.2***.

2.5.1 BIM's Cost Reduction/Control:

As it has been mentioned, the BIM application gives numerous opportunities for the reduction of project budgets through its ability to produce detailed quantity takeoffs of materials and equipment. Becerik-Gerber and Rice (2010) conducted a survey to study the perceived value of the Building Information Modeling in the US construction industry where 50% of the respondents have mentioned that using BIM resulted in up to 50% reductions of overall project costs. Manning and Messner (2008) examined a BIM project case study represented by the renovation of a Medical Research Lab in the U.S., they found that the use of BIM in this project resulted in almost 20% savings in the man hours required which translates into approximately 62% of overall project cost savings.

In a case study published by GRAPHISOFT (2015) that examined the use of BIM by SARCO Architects in Costa Rica, the company experienced large reductions in construction costs after the implementation of BIM through the ARCHICAD software, it was reported that the organization had executed almost 65-70% of its projects using this software describing it as a tool that enhances the workflow and maximizes productivity. Azhar (2011) investigated the economics of 10 BIM projects in the U.S. in ***table-1*** to examine the cost benefits of BIM; he found that all projects experienced significant cost savings ranging from $6,850 to nearly $2M with a return on investment rate from 140% to 39,900%.

Table 1: BIM Cost Savings for 10 Projects in the U.S. (Adapted from Azhar 2011, p.7)

Year	Cost ($M)	Project	BIM Cost ($)	Direct BIM Savings ($)	Net BIM savings	BIM ROI (%)
2005	30	Ashley Overlook	5,000	(135,000)	(130,000)	2600
2006	54	Progressive Data Center	120,000	(395,000)	(232,000)	140
2006	47	Raleigh Marriott	4,288	(500,000)	(495,712)	11560
2006	16	GSU Library	10,000	(74, 120)	(64,120)	640
2006	88	Mansion on Peachtree	1,440	(15,000)	(6,850)	940
2007	47	Aquarium Hilton	90,000	(800,000)	(710,000)	780
2007	58	1515 Wynkoop	3,800	(200,000)	(196,200)	5160
2007	82	HP Data Center	20,000	(67,500)	(47,500)	240
2007	14	Savannah State	5,000	(2,000,000)	(1,995,000)	39900
2007	32	NAU Sciences Lab	1,000	(330,000)	(329,000)	32900

2.5.2 BIM's Time Reduction/Control:

One of the other important success factors for BIM project is its reduction in overall project durations. It has been argued that BIM can reduce project schedules by 80% by reducing the time needed for cost estimation (Azhar, 2011). On the other hand, Gardezi et al. (2013) claim that BIM's 4D feature (project scheduling) helps contractors in exploring the phasing and sequencing of the project activities during construction as well as utilizing the schedule for the project completion. Azhar (2011) discusses the time reductions offered by the use of BIM by referring to a study by Stanford University in the U.S. which indicates that BIM can reduce overall project schedules by up to 7%. Similarly, he gives the example of the Hilton Aquarium Project in Georgia, U.S. which experienced up to 1,143 hours of schedule reductions due to its incorporation of BIM. Likewise, Manning and Messner (2008) explain BIM's project time reduction in an Expeditionary Hospital Facility where the design was initially done using traditional CAD with more than 350 drawing hours over 24 months while redoing the design using BIM required only 214 hours over 44 days, they also argue that the team had more design details at 39% of the BIM conceptual design stage than what was produced in the initial three years of the project. Moreover, Kaner et al. (2008) studied and analyzed the use of BIM in three Precast Concrete projects by mid-sized structural engineering companies; they found that the adoption of BIM resulted in man hour reduction by 2.6-47.4% measured against both the concrete quantities used and the number of drawings produced (***Table-2***).

Table 2: Project and Productivity Data for Three BIM Projects (Adapted from Kaner et al. 2008, p.309-310)

Project		Blackfoot Crossing (KD&A)	Eagle Ridge (KD&A)	Modi'in (Star)	
				Level -3.50	Level 0.00
Project Type		Architectural Precast Facade	Total Precast Structure	Prestressed Concrete Girders	
BIM working hours		489*	2,854**	124	95
Estimated CAD working hours		502*	3,583***	171	181
Productivity (hours/m^3)	BIM	6.8	0.8	1.51	1.94
	CAD	7.0	1.0	2.09	3.68
	Reduction (%)	2.6%	20.3%	27.8%	47.4%
Productivity (hours/drawing)	BIM	7.8	5.5	4.12	3.17
	CAD	8.0	6.9	5.70	6.02
	Reduction (%)	2.6%	20.3%	27.7%	47.3%

The time reductions offered by BIM on the Modi'in project are shown below in ***figure-7*** where the resulting project timeline is compared against a typical CAD timeline.

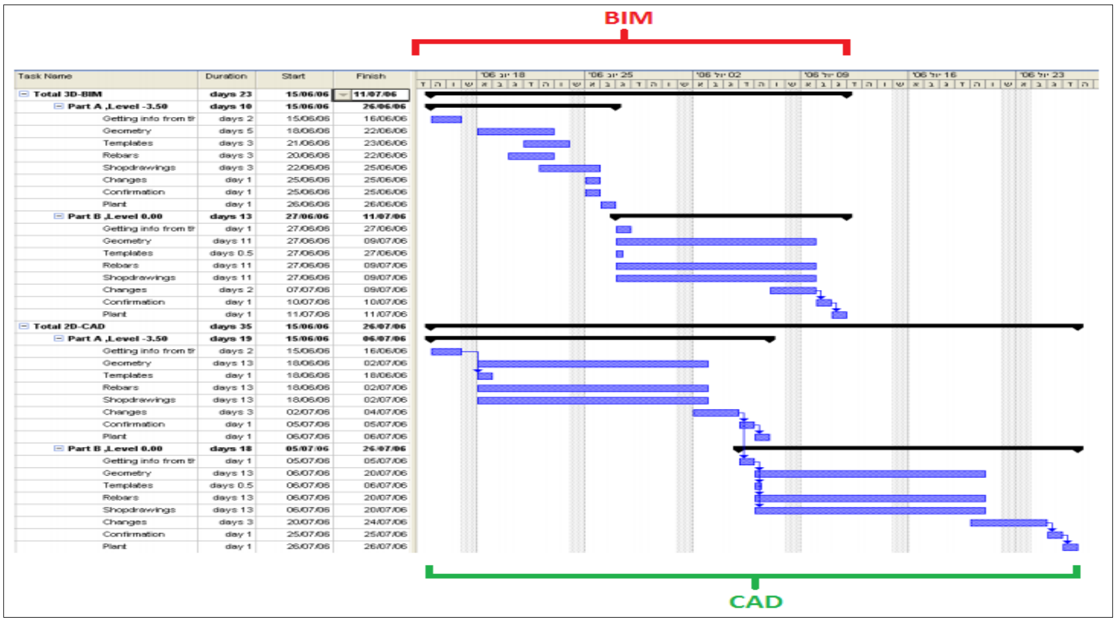


Figure 7: BIM vs CAD Gantt Charts of Modi'in Commercial Centre Project (Adapted from Kaner et al. 2008, p.315)

2.5.3 BIM's Collaboration Improvement

Enhancing collaboration and communication whether on the external level between project stakeholders or internally between project teams is one of the key benefits attributed to BIM. Azhar (2011) argues that the collaboration process in BIM projects leads to almost 40% less project discrepancies and variations; he also claims that BIM's ability to detect clashes can save up to 10% of the overall project contract value. Suermann (2009) found in an interview with a BIM Design Section Chief that BIM brings design team members together and makes them work more cohesively like a team, it also helps architects in starting their design earlier than in the traditional approach. According to the earlier mentioned study of the BIM renovation project of a Medical Research Lab by Manning and Messner (2008), the adoption of BIM in the project allowed the programming team to work in a more collaborative coordination process with the other departments through the use of basic color schemes in order to represent usage types of rooms and ownerships, this helps in updating the room conditions automatically to match the existing ones considering that it is a renovation project, it is also argued that this process eliminated more than 100 man hours needed for project owners to explore site conditions and agree on them with other stakeholders. Bryde, Broquetas and Volm (2013) found in a survey that "*3D Coordination and Design Reviews*" was ranked as the most used BIM feature among 25 other uses.

Kaner et al. (2008) found in their investigation of the Eagle Ridge Project (by KD&A) that the incorporation of BIM has eliminated the need for cross checking and coordination between drawings, they also claim that using BIM helped in avoiding any repairs due to errors in shop drawings. On the other hand, they argue that the amount of dimensions and information shown on the erection drawings was significantly reduced due to the use of BIM, whereas using CAD would have meant that more information should be presented on each drawing as the precast concrete pieces would be drawn separately. According to a report published by InfoComm International (2015), BIM gives fully detailed data of each building element and helps team members verify the compatibility of each element with the other components in the building, BIM also enhances collaboration between members through making design changes and understanding the outcomes of these changes, the report also argues that BIM's detection of collisions or clashes between elements and communicating them early in the project helps reduce the project time and costs, also the ability of BIM to create detailed views of the building such as sections, elevations and callouts helps understand the design better and eliminates the need for sketches or manual drawings.

2.6 Chapter Conclusion:

In summary, the second chapter in this paper discussed a number of BIM advantages for projects and organizations, it then selected three main benefits of BIM (cost reduction, time reduction and collaboration improvement) and expanded on each of them while giving real-life project examples that highlight how these advantages were achieved.

CHAPTER 3: RISKS OF BIM:

3.1 Chapter Introduction:

This chapter discusses the topic of risk, it begins by defining the term "risk" and explaining its involvement in the field of project management, then it presents the three types of risks associated with BIM (Technology, Process and Policy), after that the chapter invesitgates the risks under each BIM domain in more detail. The impact of the risks mentioned in this chapter on the advantages of BIM shall be examined in the conceptual model in ***Section 4.2***.

3.2 Risks in Project Management:

Definition of Risk:

The common term "Risk" usually gives the impression of a negative/undesirable event that has bad implications on its surroundings, however many researchers have tried to emphasize that a risk can be handled with either an optimistic or a pessimistic attitude, despite the numerous definitions presented in the literature, one of the most famous ones has been described by the American Project Management Institute (PMI) as "*an uncertain event or condition that, if it occurs, has a positive or negative effect on a project objective*" (Ward and Chapman 2003, p.98). The two possible scenarios of this uncertainty are sometimes described as an "Upside Risk" when it presents a prospect or a "Downside Risk" when it poses a threat (Ward and Chapman, 2003).

The topic of risk is embedded within a wide range of industries and can influence many different project factors, however Zou, Zhang and Wang (2006) claim that the most significant risks in construction projects mainly impact the time, cost and quality performance parameters. On the other hand, Chapman and Ward (2003) argue that the management of project risks should be a continuous process throughout the project's lifecycle; they also highlight the great opportunities achieved by resolving project threats and challenges.

Risk Management Strategies:

The strategies for managing risks are dependent on the effect that they might have on the project as well as the expected frequency of their occurrence, other factors may include the cost and time required for managing those risks. The most repeatedly mentioned strategies in the literature are illustrated by Elkjaer (1999) in ***figure-8*** below in the following order of action:

1. **Acceptance:** the first step in mitigating risks is usually performed when either the costs of eliminating the risk are too high or the impact or likelihood of the risk is minor. The main action performed when accepting a risk is allowing for a contingency in the project budget or time schedule for this risk to occur.
2. **Reduction:** this approach requires instant action to either minimize the impact or the likelihood of the risk. The costs of reducing the risks must be examined and compared to the savings resulted by the risk reduction.
3. **Elimination:** this method of risk management should result in the complete removal of project risks; it is followed when the impact of the risks cannot be tolerated within the project parameters. Although risk elimination is usually costly, it avoids driving the project towards a negative path.
4. **Transfer:** the last alternative of managing risks is passing them to other project parties; it is usually performed in the contractual stage of the project when the ability of each party to handle a specific type of risk is defined. Despite the fact that this approach transfers the risk to other participants, it does not indicate that the risks have been minimized or controlled.

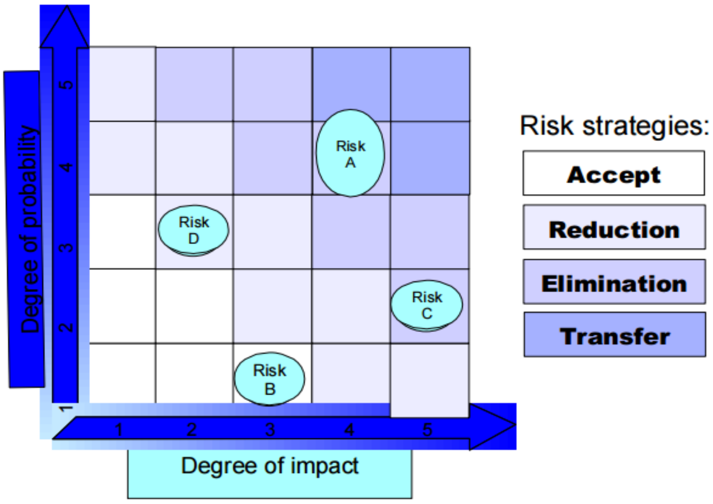


Figure 8: Risk Mapping (Elkjaer 1999, p.18)

3.3 Types of BIM Challenges in the AEC Industry:

The introduction of new applications and technologies can always create many challenges and difficulties which is the situation with the fast developing BIM technology. Abdelhady (2013) claims that the risks involved with the BIM process can be divided based on the three domains of BIM mentioned by Underwood (2009). The three BIM domains are shown below in ***figure-9***:

1. **Technology Domain Risks** (**technical**): these comprise of all challenges concerned with the technical aspects of BIM programs like software developments, networking systems and file sizes.
2. **Process Domain Risks** (**non-technical**): these consist of all organizational challenges that face BIM incorporation from clients all the way to facility managers including resources, activities, products and management issues.
3. **Policy Domain Risks** (**non-technical**): these include all challenges associated with the creation of BIM policies and standards by governing authorities and insurance companies, the new contractual relationships under the BIM system and the formation of legal contracts that address the nature of BIM projects.

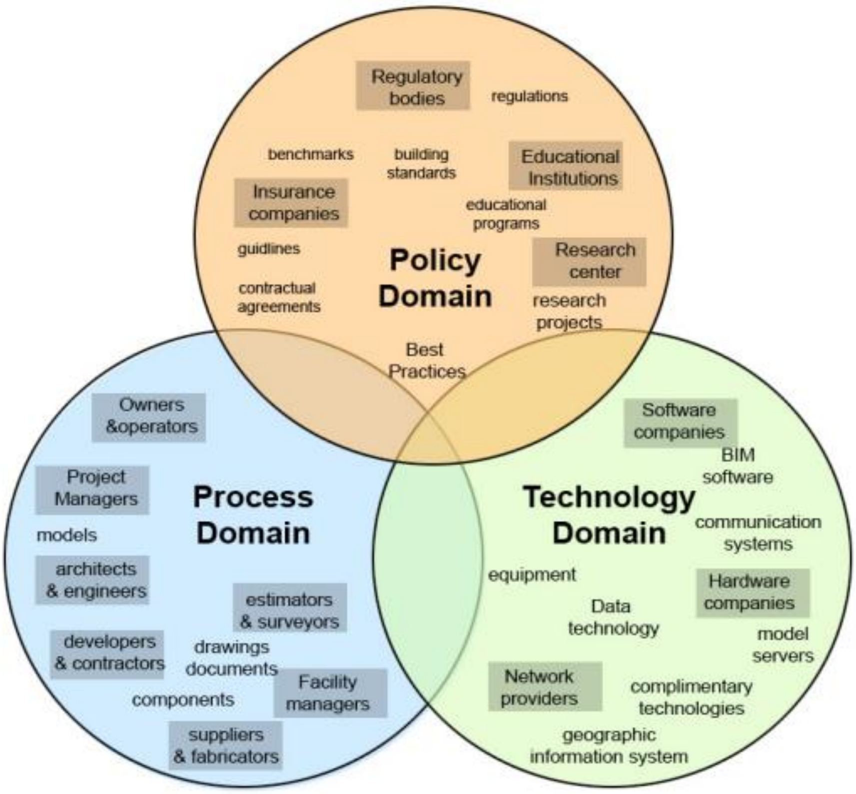


Figure 9: The Three Domains of Building Information Modeling (BIM) (Underwood 2009, p.66)

3.4 Risks of BIM:

This section discusses in further detail the risks that encounter each of the three BIM domains mentioned in ***figure-9***. The risks presented in this section are summarized at its end in ***table-3*** according to their type and literature citations.

3.4.1 Technology-Domain Risks:

Although this paper does not focus on the detailed requirements and specifications of the BIM programs and their challenges, it does however address those that have an impact on the main project parameters as well as the process of adopting BIM. It has been regarded that one of the most recurring challenges of BIM is the lack of compatibility between BIM programs which makes the data exchange process a lot more difficult and results in a major loss of valuable project data. It has also been argued that despite the fact that this risk is a technological one, it involves significant organizational changes and decision making mechanisms to create a unified information system and prevent data loss (Azhar, Khalfan and Maqsood, 2012; Goucher and Thurairajah 2012; Ku and Taiebat, 2011; Olatunji, 2011; Stanley and Thurnell, 2014; Volk, Stengel, and Schultmann, 2014). Similarly, Joseph (2011) claims that BIM's interoperability issue requires an additional position within the BIM team "*BIM Interoperability Specialist"*, this may be considered as an additional expense for the organization along with the added time for recruiting such position. Volk, Stengel, and Schultmann (2014) argue that the interoperability issue in BIM may increase because of the long lifecycles of projects as opposed to the fast development of BIM programs. It has also been debated that BIM specialists have to comprehend the drawbacks of BIM programs and the type of programs to utilize for different project types (Migilinskas et al. 2013; Stanley and Thurnell, 2014). Moreover, Furneaux and Kivvits (2008) claim that increasing the interoperability of BIM programs in the Australian industry can result in saving up to two thirds of the overall estimated $15.8 billion annual budget for BIM's incompatibility issues.

On the other hand, Arayici et al. (2011) claim that BIM's advanced hardware and programming systems usually require drastic changes in the working system of an organization which is considered as one of the risks of adopting BIM. McGraw-Hill (2010a) presents the case of a UK BIM project which encountered technical difficulties after the consultant's machines failed to handle the BIM programs used, this led to the recreation of a 2D design and an as-built BIM model after project completion. It has also been stated that the requirement of software licenses for BIM programs is considered as another risk for its incorporation due to the added expenses (Jones, 2014; Khosrowshahi and Arayici 2012). Jones (2014) further elaborates on this risk by giving the example of AECOM Engineering, Consulting and Project Management Company which came across this challenge once attempting to adopt BIM within their system, he also mentions the need for different language licenses to suit their various global branches. Many researchers have argued that the scarcity of parametric objects for BIM programs from BIM vendors as well as the lack of electronic BIM specifications for object coding and measurement are considered as some of the main barriers for the use of BIM (Manning and Messner, 2008; Masterspec, 2012; New Zealand National BIM Survey, 2013; Stanley and Thurnell, 2014).

3.4.2 Process-Domain Risks:

This type of risks is mainly focused on the collaboration challenges between stakeholders; it also addresses all aspects affecting the process that an organization has to carry out in order to implement BIM including resources, activities and management strategies. In order for the BIM operation to run smoothly and efficiently, all stakeholders involved in the project must understand the benefits of BIM and be fully committed to its implementation. Khosrowshahi and Arayici (2012) and Zahrizan et al. (2013) argue that one of the main reasons behind not adopting BIM is the clients' lack of demand for it in numerous countries. Similarly, it has been stated that the unawareness of BIM benefits and great enhancements to projects can stand in the way of its incorporation (Newton and Chileshe, 2012; Zahrizan et al., 2013). Other researchers argue that the unfamiliarity with BIM's strict implementation standards and special contractual implications creates a significant risk in the adoption process (Migilinskas et al., 2013). One of the implications of the stakeholders' unwillingness to incorporate BIM is mentioned by Manning and Messner (2008) through the example of an Expeditionary Hospital Facility where the contractor on this project was unwilling to use BIM and wanted to use the traditional CAD application instead, this resulted in a loss of data and added benefits of BIM during the transfer of information from the design to the construction stage.

Many researchers argue that the lack of stakeholder collaboration is a primary risk in the BIM incorporation process (Ku and Taiebat, 2011; Migilinskas et al., 2013; Volk, Stengel, and Schultmann, 2014). Several factors affecting the collaboration between stakeholders in BIM projects have been mentioned in the literature including both external and internal elements. Some researchers claim that the fragmentation of the construction industry stands in the way of top-level industry collaboration, the integration of a BIM database and the commitment to implement BIM (Masterspec, 2012; Stanley and Thurnell, 2014). Other researchers argued that the produced BIM models lack integration between the different engineers and designers on the project including architects and civil and MEP engineers which influences the modelling efficiency (Stanley and Thurnsell, 2014). Azhar (2011) suggests that one of the factors impacting stakeholder collaboration is the multiple added design dimensions in BIM (4D Project Scheduling and 5D Cost Estimation) leading to difficulties in unifying the software platforms between the stakeholders. Further literature addressed the issues of communication and its effect on collaboration, Eadie et al. (2013) state that the team members' refusal or reluctance to share data in an open manner jeopardizes the collaborative approach of BIM and stands in the way of its full information exchange method, they also claim that BIM's adoption might negatively impact internal team members' communication as well as interaction with clients.

Moving on to the business and operational aspects of implementing BIM within an organization, it has been stated that the impact of managerial barriers in systems similar to BIM is much larger than the one caused by technical ones, also the organizational paybacks realized by the use of BIM in re-building the business practices have to be quantified and measured (Jung and Joo, 2011). Furthermore, Eadie et al. (2013) argue that BIM's adoption in an organization impacts all its activities and work processes therefore it cannot be secluded as a purely technological system. It has been discussed that the lack of an organizational culture that supports the development, training and practice of BIM in addition to a lack of commitment from the organization's upper management can hinder the implementation process (Migilinskas et al. 2013; Volk, Stengel, and Schultmann, 2014). Similarly, it has been claimed that the natural change resistance attitude on the organizational and cultural levels can largely impact BIM's adoption (Eadie et al. 2013; Khosrowshahi and Arayici 2012; Smith, 2014; Stanley and Thurnell, 2014; Zahrizan et al. 2013).

Eadie et al. (2013) argue based on a BIM survey that organizations' failure to realize direct benefits from BIM projects is one of the main reasons for not implementing the system. However, one can argue that the reason behind not realizing BIM benefits on projects is the lack of utilization of the added BIM features, Kreider, Messner and Dubler (2010) generated a survey to investigate the frequencies and advantages of 25 BIM uses by 175 respondents as shown in ***figure-10***, they found that 18 of the BIM uses fall below 30% of utilization frequency including Cost Estimation.

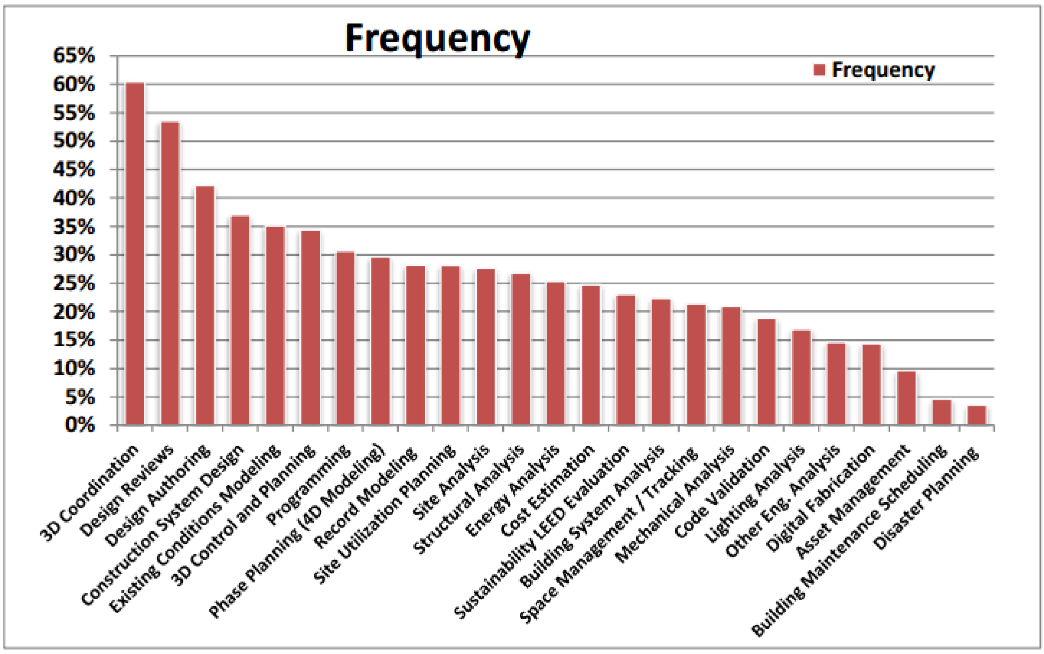


Figure 10: Frequency of 25 BIM uses across 175 industry professionals (Kreider, Messner and Dubler 2010, p.7)

Jones (2014) argues that the challenges that encounter BIM adoption are dependent on the size of the organization. Likewise, many studies that examined the relationship between firm size and its ability to incorporate BIM proposed that smaller organizations face more risks in the adoption process due to the financial and organizational difficulties (Newton and Chileshe 2012; Zahrizan et al. 2013).

Many researchers have stated that a company's lack of experience and knowledge about BIM as a whole organization poses a threat to the BIM implementation process (Eadie et al. 2013; Kashiwagi et al. 2012; Khosrowshahi and Arayici 2012; Ku and Taiebat, 2011; Mayo, Giel and Issa, 2012). Other researchers have argued that organizations fear high failure or low success in BIM projects because of the lack of BIM capability of their project teams more specifically (Azhar, Khalfan, and Maqsood, 2012; Ku and Taiebat, 2011; Mayo, Giel and Issa, 2012; Migilinskas et al. 2013; Zahrizan et al. 2013).

On a similar note, Eadie et al. (2013) found in a survey that included 92 industry professionals that the top two reasons for not implementing BIM are the lack of the project team's experience in BIM and the lack of the organization's experience in BIM. Investigating the lack of BIM skills among project teams in more detail, Wei and Raja (2014) state that BIM teams have significant shortage in skills in the two added features of BIM represented by 4D design (project scheduling) and 5D design (cost estimation), they also claim that these two features have a large value for projects and organizations. On the other hand, it has been argued that one of the issues in staff skills in BIM is their unfamiliarity with the parametric concepts in the application which basically revolve around the idea of creating project components that can automatically be adjusted using parameters (Manning and Messner, 2008; Underwood, 2009).

The added expenses of implementing BIM through cost and time have been frequently mentioned in the literature as a major barrier for BIM adoption. Many researchers claim that the large investment costs of BIM through the recruitment and training processes are considered as one of the main risks of BIM incorporation (Arayici et al., 2011; Azhar et al. 2011; Azhar, Khalfan and Maqsood, 2012; Crotty, 2012; Eadie et al. 2013; Ku and Taiebat, 2011; Migilinskas et al. 2013; Stanley and Thurnell, 2014). According to UK's National Building Specification (NBS) report in 2014, 67% of BIM-based organizations and 64% of non-BIM users agreed that the costs of BIM were among the top challenges of its incorporation. Similarly, Abanda et al. (2015) conducted a survey which investigated the feedbacks of 56 industry professionals when it comes to BIM adoption barriers, the high set-up costs as well as the licensing fees of BIM were the top two challenges of BIM incorporation. Gray et al. (2013) found in a BIM survey that construction professionals estimate the costs of adopting BIM to range between 2-15% of the overall project budget. Other researchers argued that the time used for the training and learning process in BIM is one of the other barriers to its incorporation (Migilinskas et al., 2013; Stanley and Thurnell, 2014).

3.4.3 Policy-Domain Risks:

The Risks involved with the policy domain of BIM mainly include the policies that must be created to drive the implementation of BIM, the creation of BIM standards by regulatory bodies as well as the legal issues and the involvement of insurance companies. It has been argued that one of the significant barriers to the adoption of BIM is the discrepancy in the levels and structures of BIM across different countries resulted by the governmental movements and political forces in some countries and the delayed implementation of BIM in other less developed countries (Volk, Stengel, and Schultmann, 2014). On the other hand, Azhar, Khalfan and Maqsood (2012) state that the undistributed costs of BIM operation and development among industry stakeholders is another challenge for the BIM implementation efforts, this perhaps indicates the need for industry policies that define the role of each stakeholder involved in BIM.

Several literature studies have focused on the legal aspects of BIM as well as risk sharing. Some researchers suggested that BIM's collaborative approach leads to more risk sharing and less allocation of liabilities between stakeholders (Arayici et al., 2011; Khosrowshahi and Arayici, 2012; Le Masurier, 2016; Sebastian 2011). Other researchers claimed that the lack of legal and contractual frameworks that address the nature of BIM projects has a significant effect on its adoption (Azhar, Khalfan and Maqsood, 2012; Ku and Taiebat, 2011; Porwal and Hewage, 2013; Volk, Stengel, and Schultmann 2014). Similarly, Porwal and Hewage (2013) argue that BIM addendums (documents) should be produced to identify the precise responsibilities of all project participants as many parties assume correct model input by other parties involved in the project. Many other researchers agreed that the issue of undetermined ownership of the BIM model between stakeholders is one of the major risks affecting BIM implementation (Azhar, Khalfan, and Maqsood, 2012; Khosrowshahi and Arayici, 2012; Leeuwis, Prins and Pastoors, 2013; Volk, Stengel, and Schultmann, 2014). Further studies confirmed that contracts must address the intellectual rights of BIM models as well as members' model access and control privileges as the final BIM model holds significant informational value (Porwal and Hewage, 2013; Sebastian, 2011).

3.5 Summary of BIM Risks:

The risks of BIM discussed earlier are summarized in ***table-3*** according to their type (technical, process and policy) and their literature citations. The majority of the **32** risks are associated with the process domain of BIM (**24** risks) with only **5** policy domain risks and **3** technology domain risks.

Table 3: Summary of BIM Risks according to their type and literature citations
(Source: Multiple Citations)

	Risk Factor	Type	Citations
1	Project team's lack of experience in BIM	Process	Azhar, Khalfan and Maqsood (2012) Eadie et al. (2013) Ku and Taiebat (2011) Mayo, Giel and Issa (2012) Migilinskas et al. (2013) Zahrizan et al. (2013)
2	Incompatibility of BIM programs and loss of data	Technology	Azhar, Khalfan and Maqsood (2012) Goucher and Thurairajah (2012) Ku and Taiebat (2011) Olatunji, (2011) Stanley and Thurnell (2014) Volk, Stengel, and Schultmann (2014)
3	BIM model copyrights are not defined	Policy	Azhar, Khalfan, and Maqsood (2012) Khosrowshahi and Arayici (2012) Leeuwis, Prins and Pastoors (2013) Porwal and Hewage (2013) Sebastian (2011) Volk, Stengel and Schultmann (2014)
4	Costs of training and recruitment	Process	Arayici et al. (2011), Azhar et al. (2011) Crotty (2012), Eadie et al. (2013) McGraw-Hill (2010a) Stanley and Thurnell (2014)
5	Resistance to change at cultural and operational levels and difficulty of adapting to a new system	Process	Eadie et al. (2013) Khosrowshahi and Arayici (2012) Smith (2014), Stanley and Thurnell (2014) Migilinskas et al. (2013)
6	The Organization as a whole lacks experience in dealing with the BIM system	Process	Eadie et al. (2013), Ku and Taiebat (2011) Kashiwagi et al. (2012) Khosrowshahi and Arayici (2012) Mayo, Giel and Issa (2012)
7	Cost of upgrading computers, technical support and software licenses	Process	Arayici et al. (2011), Gray et al. (2013) Jones (2014), McGraw-Hill (2010a) Khosrowshahi and Arayici (2012)
8	Lack of collaboration of stakeholders	Process	Azhar, Khalfan, and Maqsood (2012) Ku and Taiebat (2011) Migilinskas et al. (2013) Volk, Stengel, and Schultmann (2014)
9	High overall initial investment costs in BIM	Process	Azhar, Khalfan and Maqsood (2012) Eadie et al. (2013), Ku and Taiebat (2011) Migilinskas et al. (2013)
10	BIM's collaborative approach increases risk sharing between stakeholders and reduces definition of clear liabilities	Policy	Arayici et al. (2011) Khosrowshahi and Arayici (2012) Le Masurier (2016) Sebastian (2011)

Table 3 (Continued): Summary of BIM Risks according to their type and literature citations
(Source: Multiple Citations)

	Risk Factor	Type	Citations
11	Other project parties won't adapt BIM because of not knowing its benefits/preferring traditional method	Process	Khosrowshahi and Arayici (2012) McGraw-Hill (2010b) Manning and Messner (2008) Newton and Chileshe (2012) Zahrizan et al. (2013)
12	Absence of higher management support for BIM	Process	Migilinskas et al. (2013) Porwal and Hewage (2013) Sebastian (2011) Volk, Stengel and Schultmann (2014)
13	Lack of legal contracts specifically for BIM	Policy	Azhar, Khalfan and Maqsood (2012) Ku and Taiebat (2011) Volk, Stengel, and Schultmann (2014) Porwal and Hewage (2013)
14	Lack of electronic BIM standards (families, templates...etc)	Technology	Manning and Messner (2008) Masterspec (2012) New Zealand National BIM Survey (2013) Stanley and Thurnell (2014)
15	Lack of client demand in certain industries	Process	Eadie et al. (2013), Zahrizan et al. (2013) Khosrowshahi and Arayici (2012)
16	Time spent for BIM training/learning	Process	Migilinskas et al. (2013) Stanley and Thurnell (2014)
17	The fragmented nature of the construction industry (lack of high-level collaboration, creation of database and commitment to adopt BIM)	Process	Masterspec (2012) Stanley and Thurnell (2014)
18	Project concepts are produced using CAD which causes additional project cost/time	Process	Lu et al. (2007) Nisbet and Dinesen (2010)
19	Time needed to start making the initial BIM model	Process	Bryde, Broquetas and Volm (2013) Gray et al. (2013)
20	Unfamiliarity with BIM parametric concepts (parametric families)	Process	Manning and Messner (2008) Underwood (2009)
21	Difficulty of BIM adoption in small firms due to investment costs	Process	Newton and Chileshe (2012) Zahrizan et al. (2013)
22	Lack of internal team organization and definition of responsibility of members' model input	Process	Khanzode et al. (2008) Stanley and Thurnsell (2014)

Table 3 (Continued): Summary of BIM Risks according to their type and literature citations
(Source: Multiple Citations)

	Risk Factor	Type	Citations
23	BIM's difficult implementation (It has to come in level by level)	Process	Migilinskas et al. (2013)
24	Reluctance of team members to share information and communicate effectively	Process	Eadie et al. (2013)
25	Recruited or trained BIM people leave their companies	Process	McGraw-Hill (2010a)
26	Unawareness of the contractual implications of BIM implementation	Process	Migilinskas et al. (2013)
27	Long project lifetimes cannot keep up with rapid BIM technological change	Technology	Volk, Stengel and Schultmann (2014)
28	Lack of distribution of operational/developmental costs of BIM between industry stakeholders	Policy	Azhar, Khalfan and Maqsood (2012)
29	Discrepancy in the legal BIM frameworks between different countries	Policy	Volk, Stengel and Schultmann (2014)
30	BIM's collaborative approach makes project participants assume accurate input from other contributors	Process	Porwal and Hewage (2013)
31	BIM's added dimensions (cost and scheduling) create difficulty in unifying the software and analysis platforms between stakeholders	Process	Azhar (2011)
32	Gap in staff skills in 4D (scheduling) and 5D (cost estimating)	Process	Wei and Raja (2014)

3.6 Chapter Conclusion:

This chapter began by introducing the topic of risk in project management and explaining some of the methods used for risk mitigation, after that it addressed the types of risks associated with BIM based on its three domains (technology, process and policy), then it explained in further detail the risk nature of each domain and finally it summarized the aforementioned BIM risks in ***table-3*** based on their type and citations in the literature.

CHAPTER 4: CONCEPTUAL MODEL:

4.1 Chapter Introduction:

The main purpose of this chapter is to link the risks of adopting BIM mentioned in the previous chapter with the benefits of reducing cost and time and enhancing collaboration offered by BIM, the chapter presents a number of case studies where BIM's advantages have been negatively affected by its challenges and concludes with the main research hypothesis suggesting a relationship between the perceptions of industry professionals of the impact of BIM risks on its benefits and the career profiles of those professionals, the proposed conceptual model shall be examined in ***Chapter 7*** through the variance tests of the questionnaire results.

4.2 Impact of BIM Risks on BIM Advantages:

This section attempts to find a relationship between the three advantages of BIM mentioned in **Section 2.5** and the risks of BIM mentioned in **Section 3.4**. The established relationships are either a result of real-life project examples or based on the perceptions of industry professionals in published surveys.

4.2.1 Impact of BIM Risks on its Cost Reduction:

Despite the fact that BIM has proven a reduction in the overall costs of many projects, there have been a number of situations where BIM's cost reduction was affected by certain barriers. According to the earlier mentioned survey by Kreider, Messner and Dubler (2010) which examined the frequency and impact (both positive and negative) of 25 BIM uses on 175 industry professionals; it is notable that the use with the most negative responses was cost estimation, the authors argue that the reason behind this might be the negative experiences that these professionals had when using BIM for cost estimation, this might also indicate that there is a lack of knowledge about the new BIM dimension of cost estimating and the way it can be used. It has been suggested by many researchers that a large number of the organizations that use BIM still haven't utilized its cost estimation capabilities, Stanley & Thurnell (2013) found in a survey in 2011 that only 10% of Quantity Surveying companies in the UK were incorporating BIM while only half of them used BIM's 5D feature (cost estimation) to create quantity take-offs. On the other hand, the same survey indicated that the majority of respondents believe that BIM's cost estimation will make a major impact in the future on cost planning and reduction as well as increasing client satisfaction. Similar to the survey mentioned above, Cao et al. (2015) found in a study that involved construction companies in China that BIM's cost estimation has only been utilized on 29% of the surveyed projects and has been used extensively only on 6.6% of them. Furthermore, Chan (2014) found in a survey that examined the frequency of BIM use for 42 respondents in design firms that cost estimating received the lowest usage frequency among the 7 BIM uses that were studied; he also found that respondents ranked the BIM advantage of reducing project costs as the 16th out of the 18 BIM benefits investigated.

Walasek and Barszcz (2017) created a detailed cost analysis of the "Malta House" project which calculated the net profit of the project in its three years of execution, on one hand the study examined the costs of the project represented by the number of employees (architects, engineers, quantity surveyors and project managers) and their respective salaries, the costs of BIM staff training and the costs of procuring and maintaining BIM workstations, on the other hand the revenues were represented by the annual project income. The results of this cost study found that the net profit of the project was negative in the first year after adopting BIM with $130,700 added costs, in the second year the additional costs increased to $210,355 and in the third and final year they reached up to $283,825.

McGraw-Hill (2010a) conducted a survey in 2010 to investigate the business value of BIM across the industries of Europe where some of the examined projects experienced negative impacts on the cost reduction of BIM; one example is the University Campus Suffolk in Ipswich, UK which did not get the most out of BIM's typical reduced project budget due to the costs of training staff, upgrading computers and dedicating technical support for them. Similarly, Venkatachalam (2017) found in a survey that studied BIM incorporation in the UAE that the high costs of BIM adoption received the second highest rating among 20 challenges examined. Another barrier impacting BIM's cost reduction was mentioned by the senior architect in the University Campus project mentioned earlier; the issue being that most architects who had received BIM training have left the company which resulted in a need for new recruitment or training and thus extra expenses were added (McGraw-Hill, 2010a).

Another BIM project that encountered additional costs was the St. Helens and Knowsley Hospital in Merseyside, UK where the project had to be reworked using the traditional CAD method adding about £20–30k to the project budget, Nisbet and Dinesen (2010) claim that this extra cost could have been prevented if the collaborative BIM process was adopted early in the project, they also suggest that using BIM from the early project stages could have avoided the cost increase in the Palace Exchange project in Enfield, UK where the early concept stages of the project were done in CAD which meant that all drawings had to be restructured to be converted to BIM, this led to an additional cost of £60k. Moreover, Lu et al. (2007) claim that converting 2D architectural documents into 3D working models faces certain challenges, they argue that architectural information usually come in multi-dimensions and a set of interrelated documents which makes it difficult to convert into a single integrated model.

According to Ilozor and Kelly (2012), many of the case studies mentioned in the literature about the cost savings of BIM are not accurate, they claim that the $600,000 cost savings on the Hilton Aquarium project in Atlanta, Georgia, USA were on the basis of assuming conflict prevention between the mechanical and electrical disciplines by using BIM rather than on the basis of actual data, they also argue that the information published in this case study assumed that 75% of the anticipated conflict in the project could have been managed using the traditional 2D process which means that only $200,000 were saved by the use of BIM, they also went on to question the validity of the reported BIM cost savings in the literature because of the conflicting figures on BIM's Return on Investment "ROI" between different case studies. Poirier (2015) states that some literature suggests measuring the ROI of BIM by identifying its main costs including training, recruitment and software and hardware costs while other literature compares the cost of project modeling to benefits. Gray et al. (2013) examined the effects of BIM on cost, time and quality and found that one of the BIM users experienced addition of cost when using BIM described as major organizational and hardware costs with no direct benefits as well as poor software performance. Arayici et al. (2011) created a study that examines the efficiency of three major BIM programs, the study consisted of a checklist of BIM use criteria which was weighted by the senior management team of John McCall Architects in Liverpool, UK, the given weights meant how well each program met the BIM use criteria, it was notable that the license and service costs for all three programs received an average weight of 0.5 out of 1.00.

Matarneh and Hamed (2017) found in a study that examined the views of industry professionals on the advantages of BIM that the reduction of construction cost received the lowest rating among all 13 advantages investigated. Similarly, Dowhower (2010) claims based on the perceptions of local builders in Austin, Texas, U.S. that the hard costs of sustainable and affordable housing will not be considerably minimized by using BIM compared to the traditional CAD method, he argues that the reasons behind this are the number and the nature of the projects executed in BIM; as for the number, many of those local contractors take less amounts of projects which makes it less profitable compared to taking larger numbers of bids and projects, as for the type of projects Dowhower emphasizes that the pattern in the kinds of projects greatly determines how standardized the construction processes are and how focused the resources are. On the other hand, Dowhower states that the local builders might increase BIM cost savings if they had been involved in the initial design phases. Likewise, Kuehmeier (2008) highlights the difficulty of small firms to realize the cost savings of BIM after examining a small-sized construction company where he suggests that the upfront expenses including both time and money hinder the feasibility of adopting BIM.

4.2.2 Impact of BIM Risks on its Time Reduction:

Although BIM has been credited for reducing the duration of projects and saving the time needed for cost estimation and other design aspects that BIM automatically produces, there have also been project cases and literature papers that suggest otherwise. Bryde, Broquetas and Volm (2013) conducted a study to explore the positive and negative occurrences of BIM success factors in different projects; they found that BIM's "Time reduction or control" received four negative feedbacks on three different projects where all instances were resulted by the need for additional time for project modeling or reworking because of the project conversion from traditional CAD to BIM. In a similar survey, Gray et al. (2013) found that one of the surveyed BIM users experienced a negative impact of BIM on time reduction described as "Significant addition of time", the same respondent argued that BIM requires more time in the project planning stages which leads to the onsite operations' "overtaking" of the BIM process during the construction stage, he also suggested that understanding the process of BIM is not easy and that more collaboration is needed between software providers. The same survey confirms BIM's increased time in the initial project stages as most respondents agreed that BIM's major cost, time and quality benefits are during the construction stages.

Joyce (2014) claims that BIM's 4D (scheduling) feature has many limitations represented by its rigorous process of data collection and the requirement of high skills with authoring tools and knowledge of advanced scheduling mechanisms. She suggests based on the perceptions of a principal engineer who has been involved in BIM projects that some of the tools used in visualizing and analyzing project delays in a 4D model are still not fully automated considering the software available at the time. She also argues that the decision on whether to use 4D BIM depends on the amount of disputes and claims in the project as she gives an example of a cement plant project in the U.S., it appears that the use of 4D BIM on the project contributed to reaching an agreement between the project parties without resorting to court. On the other hand, she states that using 4D BIM for dispute resolutions is sometimes met with hesitancy due to the lack of knowledge of its tools as well as the investment costs involved. In addition, she claims according to a construction scheduling executive that as the project complexity increases, it becomes more difficult to create schedule simulations. Finally, she focuses on a positive side for 4D BIM tools which is the recent drop in the costs of buying them.

Another issue that might affect BIM's time reduction advantage is the lack of utilization of BIM's 4D scheduling tools, Chan (2014) found in the earlier mentioned survey of 42 respondents from design companies that "project scheduling" received the second lowest usage frequency among the 7 BIM uses examined. He also discovered that respondents rated BIM's advantage of reducing the time for project documentation and communication as the 15th out of the 18 BIM benefits studied.

4.2.3 Impact of BIM Risks on its Collaboration Improvement:

Regardless of the fact that BIM's collaboration enhancement has been credited as one of its top advantages, there are certain limitations that stand in the way of this benefit. According to the previously mentioned report by McGraw-Hill (2010a), the University Campus Suffolk project in the UK suffered from technical issues when the consultant's computers were not able to handle BIM which resulted in redoing the design in 2D and creating an as-built BIM model after completing the project, the consultant's senior architect claims that recreating the model after project completion meant that the BIM model was not a fully detailed and coordinated model. Another collaboration factor mentioned by the senior architect is that the MEP team was using a basic 3D environment rather than BIM which meant that the MEP information had to be entered again in the architectural model to complete coordination. On the other hand, Khanzode et al. (2008) reported a negative coordination instance in a BIM Medical Office Building when the project team lacked internal organization, this in turn stood in the way of realizing the full benefits of BIM. Another negative example of a BIM project has been recorded by McGraw-Hill (2010b) through the Cascadia Center when the collaboration process was affected because not all the stakeholders had adopted BIM. Similarly, Leicht nd Messner (2008) described the BIM challenges that encountered the Dickinson School of Law project when some of the assigned specialty contractors were only proficient in 2D shop drawings and were usually assigning the 3D modeling task to a third party modeler, it has been claimed that this process caused inaccuracies in the project, as a result these contractors were forced to make changes in their systems which led to additional costs and work.

Poirier (2015) argues that giving incentives for employees to learn BIM can act as a barrier for BIM implementation; he claims that incentives can constrain the collaboration process and that they influence the intentions of employees either individually or on the organizational level. This is why it is important for employees to understand the importance of BIM and what it means to each employee in terms of his/her position in the organization, realizing how BIM can improve the quality of the individual’s work can be a much stronger motivation than physical incentives. The study conducted by Gray et al. (2013) found that most of the BIM training in companies is focused on the software rather than the process itself.

One case study where BIM’s collaboration was impacted by legal issues was mentioned by Post (2011), a life-sciences building experienced a legal conflict among designers, contractors and insurance companies when the designer decided to use BIM to create a sophisticated MEP system without informing the contractor about the constrictions of the installation, project parties claim that the conflict could have been prevented by better communication and the contractor having better BIM knowledge. Another case study is the Maxima Medical Centre (MMC) in the Netherlands which was mentioned by Sebastian (2009), the project consisted of different consultants for each of the engineering disciplines and according to the progress reports of the project, the MEP consultant was incapable of using a similar BIM platform as the other parties which required continuous conversion during data exchange between the consultants.

Ilozor and Kelly (2012) attempted to summarize the reported benefits of BIM and other collaborative technologies in the literature on nine project aspects, even though BIM had reported enhancements to seven of these aspects including "Planning and conceptualization", "Schedule" and "Quality", it did not report any major benefits to "Team Work and Project Dynamics". According to the study by Bryde, Broquetas and Volm (2013) which was mentioned earlier, BIM's coordination improvement came second after software-related issues in terms of the number of negative instances among other BIM success factors with seven cases on three different projects as in ***table-4***.

Table 4: Negative Benefits of BIM Success Criterion on Examined Projects (Adapted from Bryde, Broquetas and Volm 2013, p.976)

	Negative benefit		
Success criterion	Total instances	Total number of projects	% of total projects
Cost reduction or control	3	2	5.71%
Time reduction or control	4	3	8.57%
Communication improvement	0	0	0.00%
Coordination improvement	7	3	8.57%
Quality increase or control	0	0	0.00%
Negative risk reduction	2	1	2.86%
Scope clarification	0	0	0.00%
Organization improvement	2	2	5.71%
Software issues	9	7	20.00%

4.3 List of Selected BIM Risks for Survey

As a result of the 32 BIM risks suggested in the literature in ***Chapter 3*** as well as the challenges explained in this chapter for BIM case studies, a number of 18 risk factors were selected for investigation in the survey in ***Chapter 5***, the original list has been reduced to make the survey shorter and more focused, the selected BIM risks are shown in ***table-5***

Table 5: List of Selected BIM Risks for Survey Analysis (Source: Researcher)

	Risk Factor	Type	Citations
1	Project team's lack of experience in BIM	Process	Azhar, Khalfan and Maqsood (2012), Eadie et al. (2013) Ku and Taiebat (2011), Mayo, Giel and Issa (2012) Migilinskas et al. (2013), Zahrizan et al. (2013)
2	Incompatibility of BIM programs and loss of data	Technology	Azhar, Khalfan and Maqsood (2012) Goucher and Thurairajah (2012), Ku and Taiebat (2011) Olatunji, (2011), Stanley and Thurnell (2014) Volk, Stengel, and Schultmann (2014)
3	BIM model copyrights are not defined	Policy	Azhar, Khalfan, and Maqsood (2012) Leeuwis, Prins and Pastoors (2013) Porwal and Hewage (2013), Sebastian (2011) Volk, Stengel and Schultmann (2014)
4	Costs of training and recruitment	Process	Arayici et al. (2011), Azhar et al. (2011) Crotty (2012), Eadie et al. (2013) McGraw-Hill (2010a) , Stanley and Thurnell (2014)
5	Other project parties won't adapt BIM because of not knowing its benefits/preferring traditional method	Process	Khosrowshahi and Arayici (2012) McGraw-Hill (2010b) Manning and Messner (2008) Newton and Chileshe (2012) Zahrizan et al. (2013)
6	Absence of higher management BIM support	Process	Migilinskas et al. (2013), Porwal and Hewage (2013) Sebastian (2011), Volk, Stengel and Schultmann (2014)
7	Lack of legal contracts specifically for BIM	Policy	Azhar, Khalfan and Maqsood (2012), Ku and Taiebat (2011) Volk, Stengel, and Schultmann (2014) Porwal and Hewage (2013)
8	Time spent for BIM training/learning	Process	Migilinskas et al. (2013), Stanley and Thurnell (2014)
9	Lack of electronic BIM standards (families, templates...etc)	Technology	Manning and Messner (2008) Masterspec (2012) New Zealand National BIM Survey (2013) Stanley and Thurnell (2014)
10	Lack of internal team organization and definition of responsibility of members' model input	Process	Khanzode et al. (2008) Stanley and Thurnsell (2014)
11	BIM's difficult implementation (It has to come in level by level)	Process	Migilinskas et al. (2013)
12	Cost of upgrading computers, technical support and software licenses	Process	Arayici et al. (2011), Gray et al. (2013), Jones (2014) Khosrowshahi and Arayici (2012), McGraw-Hill (2010a)
13	Team members won't share information	Process	Eadie et al. (2013)
14	Project concepts are produced in CAD	Process	Lu et al. (2007) Nisbet and Dinesen (2010)
15	Time needed to start making the BIM model	Process	Bryde, Broquetas and Volm (2013) Gray et al. (2013)
16	Recruited or trained BIM people leave their companies	Process	McGraw-Hill (2010a)
17	Unfamiliarity with BIM parametric concepts (parametric families)	Process	Manning and Messner (2008) Underwood (2009)
18	Gap in staff skills in 4D (scheduling) and 5D (cost estimating)	Process	Wei and Raja (2014)

4.4 Hypotheses and Conceptual Model:

The final part of this chapter uses the information collected from the literature concerning the challenges of BIM and their effect on BIM's advantages to create a conceptual framework around two suggested hypotheses, these hypotheses either prove or reject the assumption that the impact rating of BIM risks (process, policy and technology risks) on its three advantages (cost reduction, time reduction and collaboration improvement) is dependent on the demographic characteristics of industry professionals (type and size of organization, position and general and BIM experience).

H_0: **Null Hypothesis** – There is no significant difference between the respondents' rating of the impact of BIM risks on its advantages based on their professional backgrounds.

H_1: **Research Hypothesis** – There is a significant difference between the respondents' rating of the impact of BIM risks on its advantages based on their professional backgrounds.

The final conceptual model with the above mentioned hypotheses is shown in ***figure-11***.

Conceptual Model

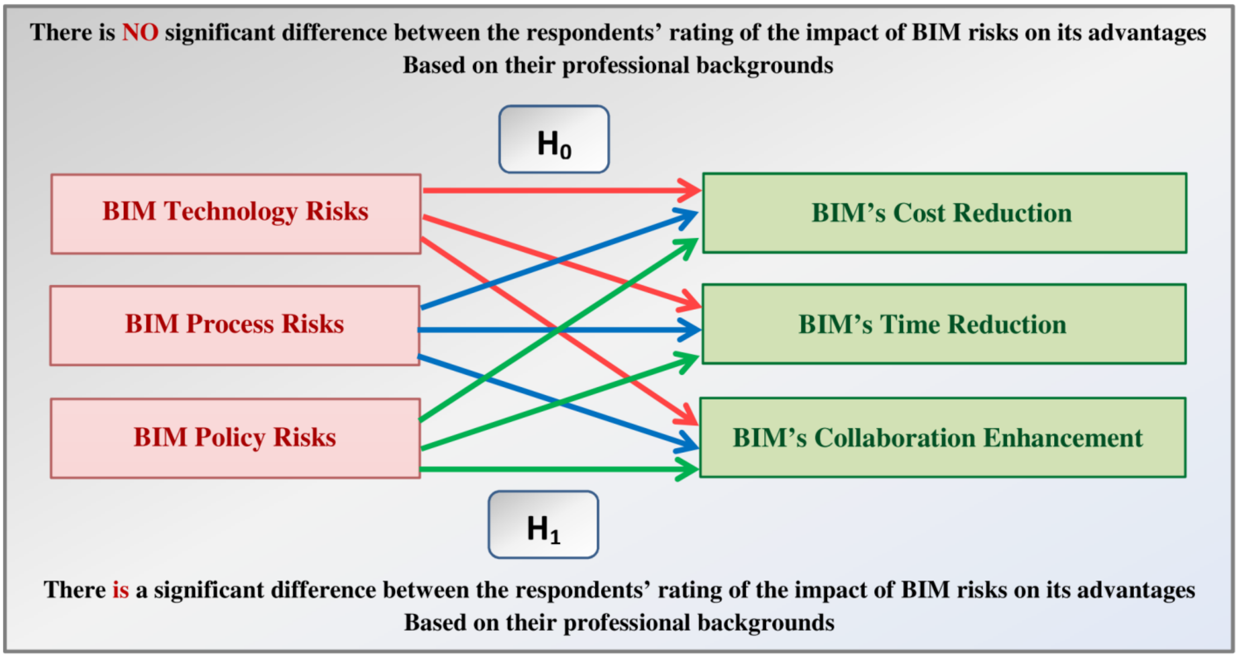


Figure 11: Conceptual Model for the Impact of BIM Risks on its Advantages (Source: Researcher)

4.2 Chapter Conclusion:

In summary, this chapter talked about the link between the challenges of BIM dicussed in ***Chapter 3*** and the advantages of BIM mentioned in ***Chapter 2***, it examined case studies in the literature where BIM's advantages were affected by the risks surrounding the BIM process and it concluded by establishing a conceptual framework that proposes a research hypothesis with the argument that the ratings of industry professionals for the impact of BIM risks on its advantages are dependent on their professional backgrounds.

CHAPTER 5: RESEARCH METHODOLOGY:

5.1 Chapter Introduction :

This chapter explains the descriptive and statistical research methods used in this paper through the survey distributed to industry professionals to study the impact of the organizational risks of BIM on its main advantages as well as conducting an interview with a Senior Products Manager in an International Design Firm to verify the findings from the literature and support the survey, these methods contribute to either proving or rejecting the research and null hypotheses suggested in ***Chapter 4***, this chapter also illustrates the selected survey sample, the nature of the questions in the survey and the interview and the proposed tests for analyzing the survey results.

5.2 Main Research Approach :

The process of analysis starts by dividing the research tools into two: descriptive and statistical. The **Descriptive** part explains the first section of the survey which examines the professional characteristics of the respondents; it also illustrates the reliability of the survey results using the values of Cronbach Alpha, the frequency distributions of the ratings of certain BIM risks, the means and severity indices of the risks and their subsequent rankings under each BIM advantage and based on the respondents profiles (nature and size of organization, role and general and BIM experience) and finally the descriptive analysis concludes in the last chapter of this research by explaining a few of the suggested strategies for managing BIM risks in the interview on the global, industry, organization and team levels.. The **Statistical** part of the analysis uses two types of variance tests to determine if there is any difference in the respondents' rankings of BIM risks based on their professional characters explained earlier, the first test is an independent t-test (for demographic classes with two groups) and the second is an ANOVA Test (for classes with more than two groups), then a factor analysis process is performed through a KMO & Bartlett Test, a Total Variance test and a Rotated Component Matrix to eliminate any inconsistent factors and group the BIM risks based on the reduced components, the reliability of these groups is tested to determine the ones with significant correlations. The last part of the analysis attempts to link the outcomes of the literature, the survey and the interview and discusses the results of the variance tests mentioned earlier to test the research hypothesis suggested in the conceptual model.

5.3 Research Instrument 1: ***Survey***

As mentioned earlier, the questionnaire was created to examine the feedback of industry professionals on the impact of BIM challenges on three key BIM success factors: BIM's Cost Reduction, BIM's Time Reduction and BIM's Collaboration Improvement.

5.3.1 Targeted Survey Sample:

In order to achieve representable data, the selected ***Sample Frame*** for the survey comprised industry professionals who have been associated with BIM one way or another; some have professional experience in BIM projects while others have basic knowledge about the BIM application and its uses. The ***Method of Sampling*** is "***Random Sampling***" meaning that the respondents have been chosen in a random manner from the larger sample frame (population). The population size could not be determined due to the lack of reliable sources on the percentage of people with BIM experience/knowledge in the UAE. The targeted sample size was **30** which have been defined by Johanson and Brooks (2010), p.395 as a "*reasonable minimum sample size for bootstrapped confidence intervals*", according to Efron and Tibshirani (1994), bootstrapping is linked to any statistical test with a random sampling method. The achieved sample size is **31** respondents. Many other researchers have suggested such sample sizes for pilot studies which Hulley et al. (2013) describes as a small scale study to examine statistical variability among other things, Isaac and Michael (1995) argued that sample sizes between 10 and 30 simplify the process of analysis and hypothesis testing, Hill (1998) agreed.

5.3.2 Survey Pre-testing and Modification:

The questionnaire was initially given to a small number of people to examine their feedback regarding the nature of the questions; the main confusion in the initial survey was in the format of the last question (examining the impact of BIM risks on its advantages) because of the negation form used (BIM's risks have negative statements while BIM's advantages also included negative phrases such as "BIM's Reduction of Project Costs"), as a result a few modifications were done to the question format and the survey was tested again to avoid any misunderstandings.

5.3.3 Survey Structure, Variables and Scale of Data

The first part of the survey establishes a descriptive profile of each respondent to be able to relate their BIM risk ratings to their respective career and BIM profiles. This section contains **9** questions that examine the type and size of organization of the respondents, their role in the company, the number of years of overall and BIM experiences, whether respondents' organizations use BIM and for how long/the percentage of projects executed using BIM and if not, when do they expect their organizations to start using it. The second part of the survey examines the impact of BIM challenges on its three main advantages (cost reduction, time reduction and collaboration improvement), the risks of BIM examined in the survey came as a result of two investigations: the challenges in ***Section 3.4*** suggested by the papers and journals in the literature and the real-life project examples mentioned in ***Section 4.2*** by published BIM studies. The wording of the selected 18 BIM risks in ***Section 4.3*** was simplified to help the respondents understand the survey better. After that a matrix of these BIM challenges against the three BIM advantages was created to establish a weight factor of the impact of each BIM challenge on each of the advantages.

The **variables** under examination are of two types:

1. **Dependent Variable: The impact of BIM risks on its Advantages**, this variable is assumed to be dependent on the independent demographic variables of the respondents (Research Hypothesis **H_1**). A "Likert" scale is used for this variable (a five-category scale), some researchers like Jamieson (2004) argue that despite the fact that the categories in this scale have a ranking order, the intervals between those ranks cannot be assumed to be equal, therefore this variable is considered to have an **interval/continuous** scale of data.

2. **Independent Variables: The Demographic Characteristics of Respondents**, where five groups that are concerned with the professional backgrounds of the respondents are assumed to be independent of each other but at the same time they are assumed to have an effect on the impact of BIM risks on its advantages. The five groups are: **Nature and Size of Organization, Position, General and BIM Experience**. The scale of the data under these variables is considered to be **Nominal**; this scale is used for categorical data where the categories do not have a specific score/rank which is the case with the five groups mentioned (consultant/contractor, small/large organization, architects/non-architects and experienced/less experienced).

5.3.4 Data Collection Method

The survey was created on an online survey website and communicated via emails, social media posts/messages and phone messages, respondents were guaranteed full discretion and when possible, assistance was given to them.

5.3.5 Survey Coding for SPSS Analysis

The first part of coding the survey for the analysis in SPSS software is creating codes for each of the 18 BIM risks where Technology risks were named "T.1, T.2", Policy risks "PL.1, PL.2" and Process risks "PR.1, PR.2" as in ***table-6***.

Table 6: Coding of BIM Risks for SPSS Analysis

T.1	Incompatibility of BIM programs and loss of data
T.2	Lack of electronic BIM standards (families, templates...etc)
PL.1	BIM model copyrights are not defined
PL.2	Lack of legal contracts specifically for BIM
PR.1	Project team's lack of experience in BIM
PR.2	Costs of training and recruitment
PR.3	Other project parties won't adapt BIM because of not knowing its benefits/preferring traditional method
PR.4	Absence of higher management support for BIM
PR.5	Time spent for BIM training/learning
PR.6	Lack of internal team organization and definition of responsibility of members' model input
PR.7	BIM's difficult implementation (It has to come in level by level)
PR.8	Cost of upgrading computers, technical support and software licenses
PR.9	Team members won't share information
PR.10	Project concepts are produced using CAD
PR.11	Time needed to start making the initial BIM model
PR.12	Recruited or trained BIM people leave their companies
PR.13	Unfamiliarity with BIM parametric concepts (parametric families)
PR.14	Gap in staff skills in 4D (scheduling) and 5D (cost estimating)

The second part of the coding process is creating the different variables mentioned earlier which will help in the analysis of the impact of BIM risks in relation with the demographic factors of the respondents, ***table-7*** shows how a **Scale**-type variable was used for variables with continuous data such as the "Respondent" variable that includes the response of each of the 31 respondents, in addition to that the variable selected for the impact of BIM risks on its advantages with answers of multiple categories was also considered to have a **Scale** type (assumed to be continuous). On the other hand, the five factors from the general information part of the survey were used as **Nominal**-type variables with values representing the different groups under each variable.

Table 7: List of Survey Variables in SPSS Software

	Name		Values	Measure
1	Participant		None	Scale
2	Demographic Variables	Type of Organization	1 = "Consultant" 2 = "Contractor"	Nominal
3		Size of Organization	1 = "Less than 100 Employees" 2 = "More than 100 Employees"	Nominal
4		Role	1 = "Architect" 2 = "Other (Engineer, Draftsman, BIM/Design Manager)"	Nominal
5		Experience	1 = "Less than 5 years" 2 = "More than 5 years"	Nominal
6		BIM Experience	1 = "None" 2 = "Less than 5 years" 3 = "More than 5 years"	Nominal
7	**Impact of each BIM Risk** *(once for each BIM advantage)*	PR.1 T.1 PL.1 PR.2 PR.3 PR.4 PL.2 PR.5 T.2 PR.6 PR.7 PR.8 PR.9 PR.10 PR.11 PR.12 PR.13 PR.14	0 = "Very Unlikely to Affect" 1 = "Unlikely to Affect" 2 = "Neutral" 3 = "Likely to Affect" 4 = "Very Likely to Affect"	Scale (continuous)
Scale	Given to variables with a **continuous scale of data**			
Nominal	Given to variables with different categories (**no** ranking/score)			

The final part before beginning the analysis in SPSS was entering the data for each of the 31 respondents as shown below in ***figure-12***.

(Repeated for each BIM advantage)

Demographic Answers

Rating of Impact of BIM Risks on its Advantages

Different Respondent Answers

Participant	CompanyType	CompanySize	Role	Experience	BIMExperien...	CompanyUse BIM	PR.1	T.1	PL.1
1	1	2	2	2	3	1	4.00	3.00	2.00
2	1	1	2	1	2	2	1.00	1.00	1.00
3	2	1	2	1	1	2	4.00	4.00	4.00
4	2	1	1	1	1	2	2.00	3.00	3.00
5	1	2	2	1	1	2	4.00	4.00	3.00
6	1	1	1	1	1	2	1.00	1.00	3.00
7	1	1	1	1	1	2	1.00	1.00	1.00

Figure 12: Data View in SPSS Software

5.3.6 Proposed Analysis Tests

The first test that will be used is a frequency analysis test, this type of test investigates the rate of the five different rating responses (very unlikely to affect, neutral…etc) for each BIM risk in order to analyze the distribution of the answers and reach further conclusions on the respondents certainty/uncertainty about those risks. After that the average weighted mean and the severity index for the impact of BIM risks on its advantages is calculated to reach a ranking of the most influential risks under each BIM advantage. Then, the ranking is repeated for each demographic group in order to determine any noticeable differences in the ratings of respondents. Next, two tests are used to statistically confirm these differences based on the demographic backgrounds of the respondents, according to ***table-8*** by Newsom (2013) and based on the assumption that the independent variables (demographic groups) consist of nominal (categorical) scale of data while the dependent variable (impact of BIM risks on its advantages) has a continuous scale of data, the selected tests for examining the variance are an independent t-test (groups with two categories) and an ANOVA test (groups with more than two categories). A list of the analysis tests and their purposes is shown in ***table-9***.

Table 8: Statistical Hypothesis Tests based on the type of dependent & independent variables (Newsom 2013, p.1)

		Dependent Variable	
		Discrete	**Continuous**
Independent variable	**Discrete** (binary and categorical)	Chi-square Logistic Regression Phi Cramer's V	t-test ANOVA Regression Point-biserial Correlation
	Continuous	Logistic Regression Point-biserial Correlation	Regression Correlation

Table 9: Proposed Analysis Tests and their purposes (Source: Researcher)

Test Name		**Purpose**
Frequency Analysis		Understand distribution of responses under BIM risks
Ranking of BIM risks based on their impact on each of BIM's three advantages		Using Weighted Means and Severity indices of Impact Ratings to find general ranking of BIM risks
Ranking of BIM risks based on the demographic groups of respondents		Find ranking of BIM risks based on respondent profiles
Reliability Test of Impact Ratings		Check the validity of survey results
Variance Analysis	Independent T-Test	Investigate any variance in respondents' rating of BIM risk impact on its advantages based on professional backgrounds
	One-Way ANOVA Test	
Factor Analysis	KMO & Bartlett Test	Check sample adequacy for factor analysis
	Total Variance	Reduction of the 18 BIM risks through the resulting component groups
	Rotated Matrix Component	
Reliability of Components		Verify the grouping of the factor analysis process

5.4 Descriptive Instrument: *Interview*

Conducting interviews is a means of collecting more detailed data and allowing for further explanations by the people being interviewed rather than a limited choice of answers as in surveys, interviews also give a chance for interaction between the interviewer and the interviewee as well as allowing the interviewer to request further clarifications on certain points that might be ambiguous.

5.4.1 Profile of Interviewee

The person who has been selected for the interview comes from a highly sophisticated background with many years of experience in the construction field and the BIM technology in specific; he previously held the title "Design Systems Manager" and currently holds the title of "Senior Products Manager" in a large multinational British engineering, design, planning, project management and consulting company.

5.4.2 Structure of Interview and Contribution to Research

The main contribution of the interview comes from targeting the main challenges that face the implementation of BIM in order to support the findings from the literature and the questionnaire. The interview also focused on proposing solutions for the global BIM challenges, contractual and legal barriers that encounter BIM incorporation, the internal organizational BIM risks and the obstacles facing team members such as communication and information sharing.

5.5 Chapter Conclusion:

In conclusion, this chapter started by discussing the data collection methods used in this research (descriptive and statistical), after that it explained the survey sampling, structure and method of data collection as well as the analysis tests that will be used in **Chapters 6-8**, finally the interview with a Senior Products Manager was briefly explained and how it contributes to this research.

CHAPTER 6: DESCRIPTIVE ANALYSIS:

6.1 Chapter Introduction:

The sixth chapter of this paper demonstrates the descriptive results of the questionnaire such as the different backgrounds of the respondents (experience, role…etc), it then discusses how these backgrounds might have an impact on the results of the survey, after that the survey validity is examined through the values of Cronbach Alpha of the responses, furthermore an analysis of the different types of frequency distributions for the BIM risk ratings is conducted. Finally, this chapter moves on to rank the BIM risks based on their impact on each of BIM's advantages first and then according to each demographic group of the respondents.

6.2 Descriptive Statistics (General Information of Respondents)

This section illustrates the demographic distribution of the respondents (percentages) according to each of the general information answers in the first part of the survey.

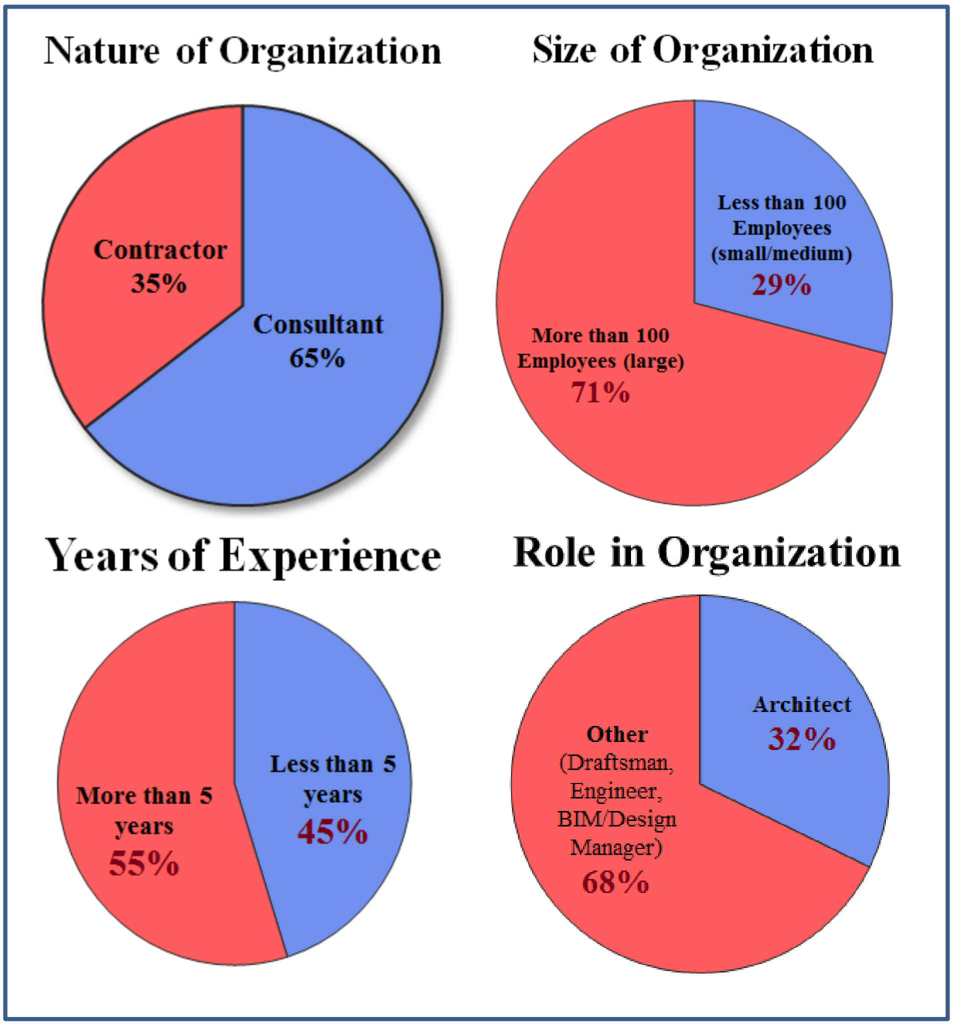


Figure 13: Descriptive Results of Survey (Source: Researcher)

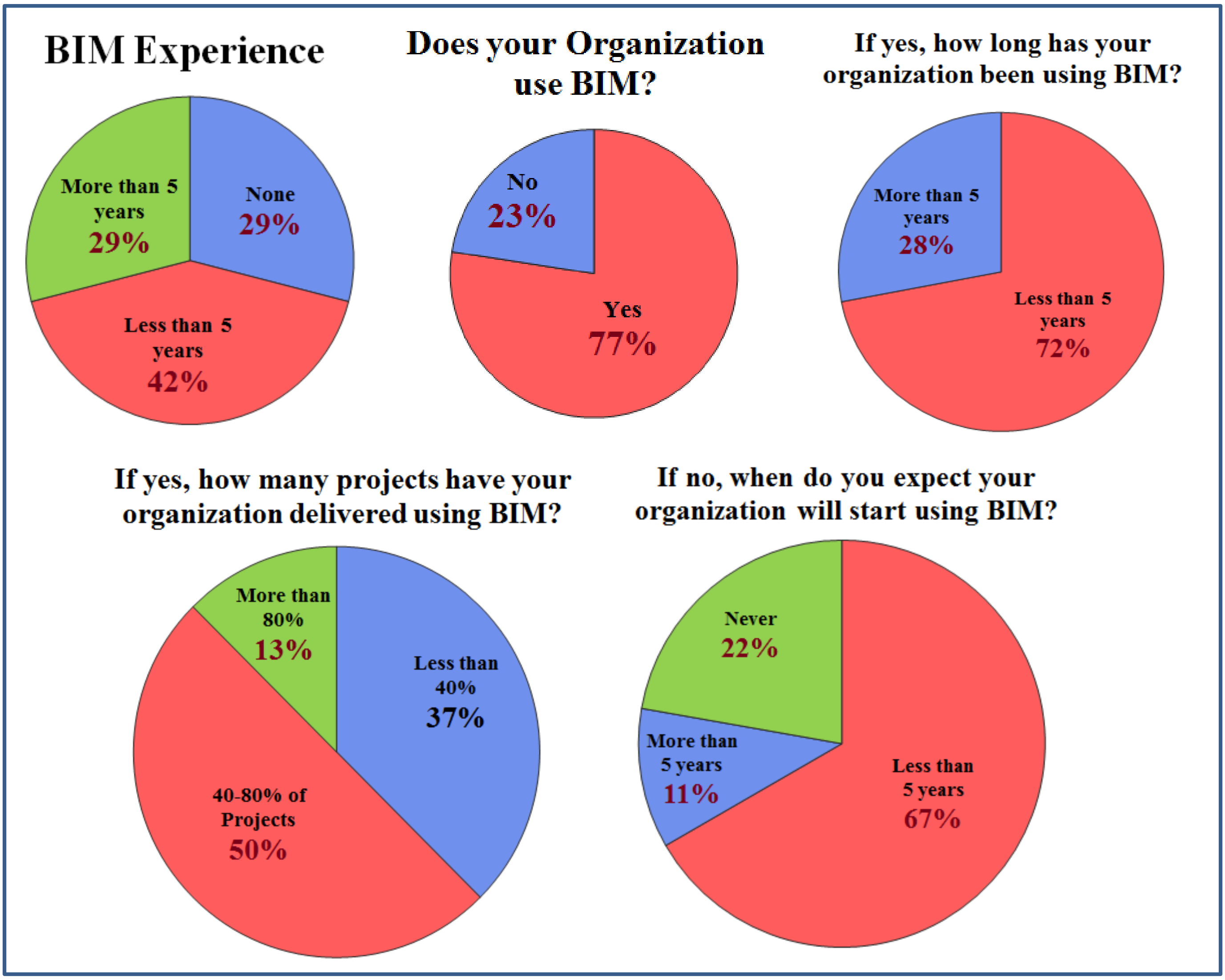


Figure 13 (Continued): Descriptive Results of Survey (Source: Researcher)

To summarize the descriptive results of the survey, almost two thirds of the respondents came from **consulting** companies (65%), the expected implications of this on the results is that the ratings of the impact of BIM risks for consultants are expected to be higher than contractors, the reason behind this is that many studies including the *SmartMarket* report by Jones (2015) found that BIM has proven to offer more benefits to contractors than consultants, the same report showed that contractors are more optimistic regarding BIM's cost reduction while consultants have a better outlook for the time reduction advantage, this might result in having higher ratings for challenges related to cost as compared to time/schedule since the majority of respondents are working in consulting firms. Another implication is that the challenge of certain project parties not adopting BIM might be ranked among the top risks by respondents from consulting organizations as indicated by Manning and Messner (2008) in an Expeditionary Hospital Facility where the contractor was unwilling to incorporate BIM.

Almost one third of the respondents are **architects** (32%) with the rest combined into one group due to the small number of respondents (draftsmen, engineers and BIM/design managers), this may result in an overall smaller rating for the incompatibility issue of BIM in conjunction with the finding in the survey by Jones (2015) that engineers perceive data exchange and incompatibility as a less important barrier than architects. The same report suggested that engineers identify the lack of skills in using advanced technologies as a bigger challenge than architects.

71% of the respondents work for relatively **large organizations** (more than 100 employees) which may result in the highest ranked risks being related to collaboration and communication (as stated in the interview in ***Appendix F***) rather than direct investment challenges such as costs of BIM hardware/software.

Experienced respondents (more than 5 years) are slightly more than those with less than 5 years of experience (55% to 45%) which cannot help in assuming any implications on the results since the two groups are almost equal, most of the respondents have **less than 5 years of BIM experience** (42%) with the remaining split into two equal groups (no BIM experience and more than 5 years), this means that 71% of the respondents have small or no experience in BIM which may result in an overall increase in respondents' ratings of the impact of BIM risks due to their lack of understanding of the technology in general and their tendency to exaggerate in rating its challenges. It is also expected that respondents with no/small BIM experience might have higher ratings for cost challenges and/or higher overall ratings for the cost reduction advantage, this assumption is due to the study by McGraw-Hill (2010b) which found that the more BIM experience people have, the higher they perceive the ROI (Return on Investment) of BIM. Moreover, nearly half of the experienced respondents have more than 5 years of BIM experience, only one experienced respondent has no BIM experience even though his/her organization does use the BIM application. All respondents with more than 5 years of BIM experience are not architects which interestingly matches the case with the BIM survey by Chien, Wu, and Huang (2014). Another implication of the BIM experience levels is that there might be a smaller rating for technology-related challenges as suggested in the survey by Underwood et al. (2015) which found that the more BIM experience respondents have, the more significant perception they have of BIM technology barriers.

The final part of the demographical statistics shows recent yet large BIM adoption rates in the industry as 77% of respondents' organizations **use BIM** of which **only about quarter** have used it for **more than 5 years** (28%), half of these organization have used BIM on **40-80% of their projects**, finally almost two thirds of the respondents whose organizations don't use BIM expected they will **start using it in less than 5 years**.

6.3 Reliability Test

The purpose of conducting this test is to examine the consistency of the BIM risk ratings by the 31 different respondents; the reliability is measured through the values of ***Cronbach's Alpha*** of the weighted means for the impact of the 18 BIM risks under each of its advantages, all values above **0.7** are considered highly reliable. As shown in tables 10 & 11, fortunately all BIM risks received values of Cronbach's Alpha above 0.7.

Table 10: Cronbach's Alpha Values for the Impact of BIM's Risks on its advantages

BIM Risk	Cronbach's Alpha if Item Deleted		
	BIM's Cost Reduction	BIM's Time Reduction	BIM's Collaboration Improvement
T.1	0.873	0.864	0.859
T.2	0.875	0.861	0.860
PL.1	0.888	0.892	0.875
PL.2	0.876	0.877	0.862
PR.1	0.870	0.862	0.872
PR.2	0.883	0.883	0.874
PR.3	0.881	0.869	0.866
PR.4	0.873	0.877	0.860
PR.5	0.883	0.884	0.883
PR.6	0.874	0.861	0.860
PR.7	0.875	0.871	0.864
PR.8	0.883	0.888	0.871
PR.9	0.873	0.866	0.865
PR.10	0.880	0.865	0.867
PR.11	0.879	0.877	0.870
PR.12	0.883	0.872	0.868
PR.13	0.874	0.866	0.864
PR.14	0.881	0.874	0.867

Table 11: Overall Cronbach's Alpha Values under each BIM advantage

BIM Advantage	Overall Cronbach's Alpha
BIM's Cost Reduction	0.884
BIM's Time Reduction	0.879
BIM's Collaboration Improvement	0.874

6.4 Frequency Analysis for Impact of BIM Risks

The purpose of this type of analysis is to study the distribution of responses that some of the BIM risks received. The two main types of ratings are:

1- Uncertain Impact Ratings: This kind of rating frequencies highlights the risks that respondents were most unclear about, even though most of these instances are present in BIM's collaboration improvement, the risks that received those ratings were not clear collaboration challenges such as costs of software and hardware, time required for building the BIM model as well as legal issues including model ownerships and BIM contracts. Moreover, the uncertain ratings occurred in one of two forms:

A- Normal Distributions: meaning that the data median (midpoint) is the neutral point in the data scale and thus the data is almost evenly distributed around the neutral rank or that the data mode (most occurring value) is the neutral rating; this means that most of the respondents gave an "uncertain" rating for the impact of a specific BIM risk on one of its advantages. There are a couple of instances with this type of distributions among all three BIM advantages; it is notable that respondents were very uncertain when it comes to the policy risks of BIM ("PL.1" undefined BIM model copyrights and "PL.2" lack of BIM legal contracts) which can be seen in ***figures-14 & 15***.

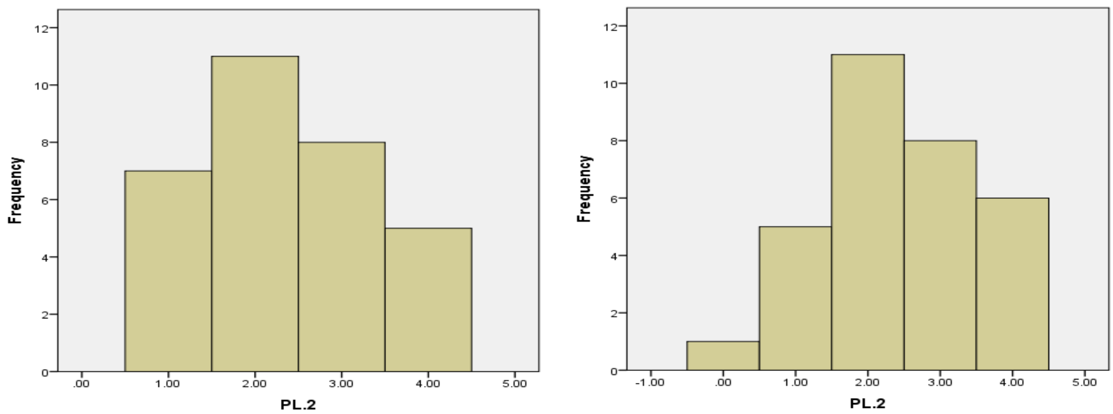


Figure 14: Frequency Analysis of "PL.2" risk impact on BIM's cost reduction (left) and collaboration enhancement (right)

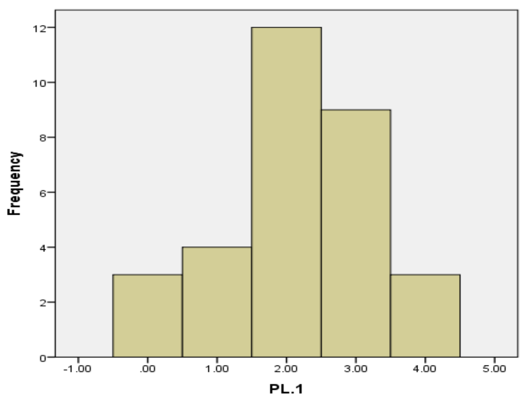


Figure 15: Frequency Analysis of "PL.1" risk impact on BIM's time reduction

Other examples of this distribution are expected like the uncertainty about the impact of direct time and cost risks ("PR.11" time to create initial BIM model and "PR.8" hardware/software costs of BIM) on collaboration enhancement as in ***figure-16***.

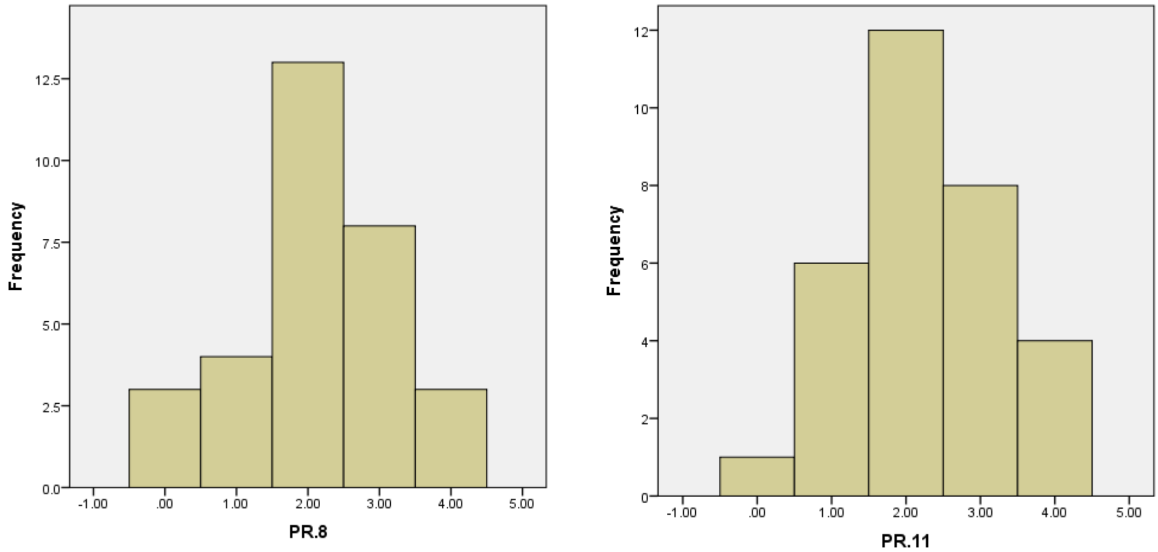


Figure 16: **Frequency Analysis of "PR.8" & "PR.11" risks' impact on BIM's collaboration enhancement**

B- Uniform Distributions: where the data has more than one mode (most occurring value) meaning that the responses are largely divided among all or most of the possible answers, an example of this type of distribution is shown in ***figure-17*** where the impacts of "T.1" incompatibility of BIM programs on its cost reduction and collaboration improvement received noticeably different responses across the sample, this means that not all respondents agree on the effect of BIM incompatibility issues and the resulting loss of data on its overall collaborative process.

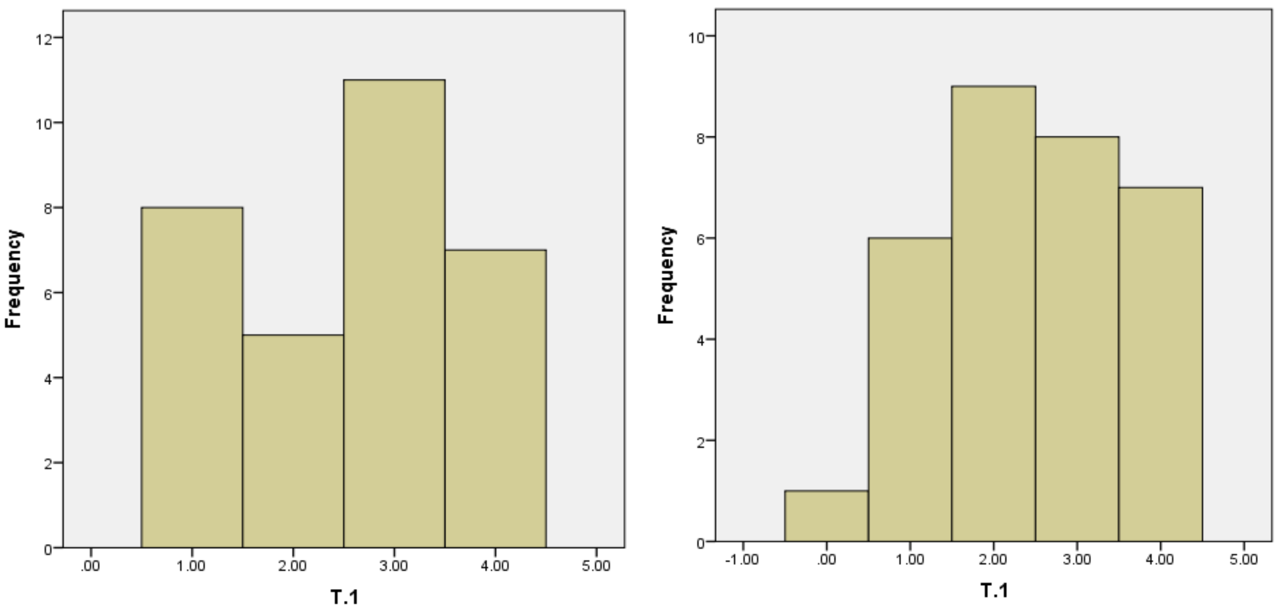


Figure 17: **Frequency Analysis of "T.1" risk impact on BIM's cost reduction (left) and collaboration enhancement (right)**

As noted earlier, most of the uncertain ratings in the survey are with BIM's collaboration improvement, ***figure-18*** shows two examples of "*Bimodal Distributions*" under collaboration enhancement where two rating weights with different interpretations (neutral and likely to affect) received similar frequencies (both are modes), it appears from the figure that respondents had differing views on the impacts of "PR.14" lack of staff skills in 4D and 5D BIM modelling and "PR.10" execution of project concepts in CAD on the collaboration improvement advantage.

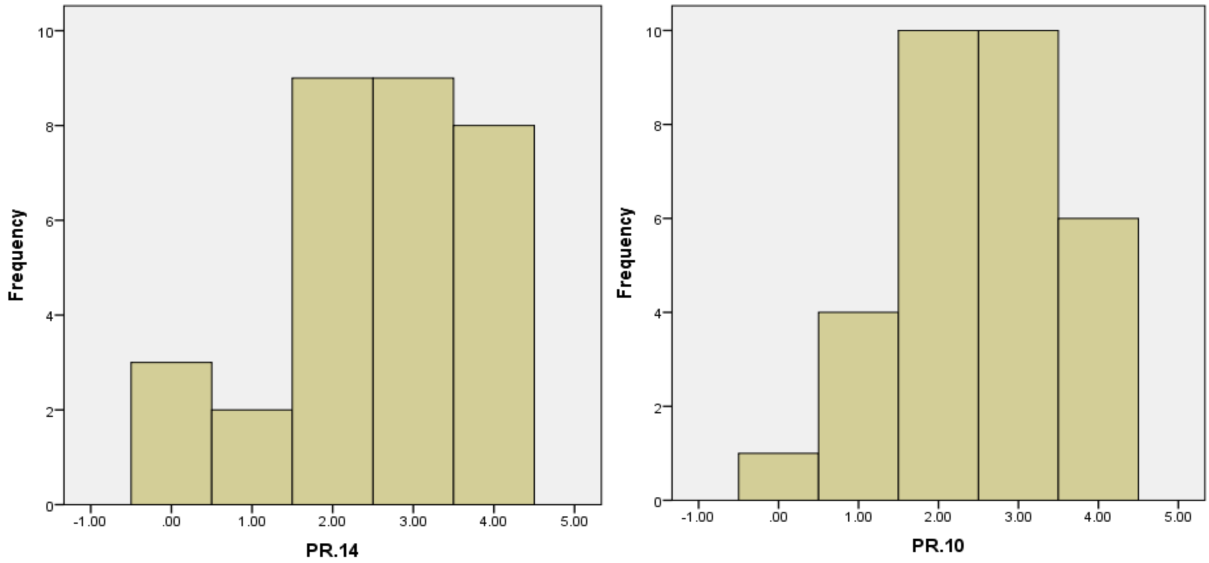


Figure 18: Frequency Analysis of "PR.14" & "PR.10" risks' impact on BIM's collaboration enhancement

On the other hand, ***figure-19*** highlights that respondents were also uncertain about the impact of "PR.5" BIM training/learning time on collaboration which can be expected since this risk is a direct time challenge; this means that some respondents believe it might have an indirect effect on collaboration while others are not sure.

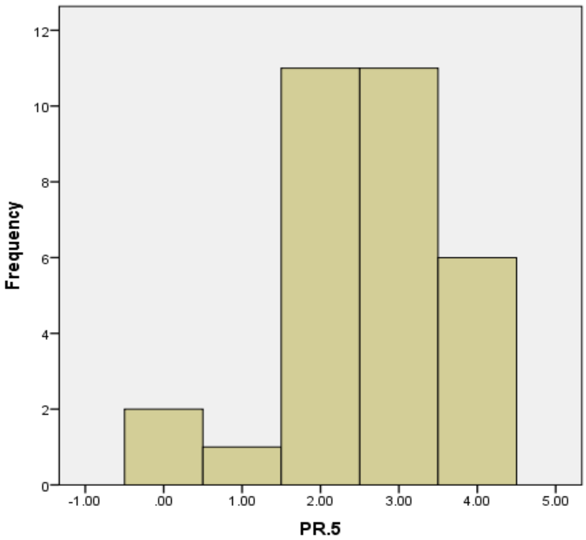


Figure 19: Frequency Analysis of "PR.5" risk impact on BIM's collaboration enhancement

2- Negative Impact Ratings: This type of ratings is when the overall data distribution of a BIM risk shows that it does indeed have a negative effect on one or more of BIM's advantages, there are different types of this rating including:

A- Unanimous Ratings** (High Negative Skewness)**: where the mode (most occurring value) is focused on the right side of the neutral point on the data scale; this means that the majority of respondents agreed on the negative impact of a certain BIM risk, however the percentage of agreement is different from one case to another. ***Figure-20*** shows two of the highest agreement rates on negative impacts where the first one demonstrates that the impact of "PR.3" Other project participants not incorporating BIM on its cost reduction received a "likely to affect" answer from nearly half of the respondents (48%). The second example shows an even higher level of agreement where 64.5% rated the impact of "PR.9" Reluctance of team members to share information as "most likely to affect" BIM's collaboration improvement.

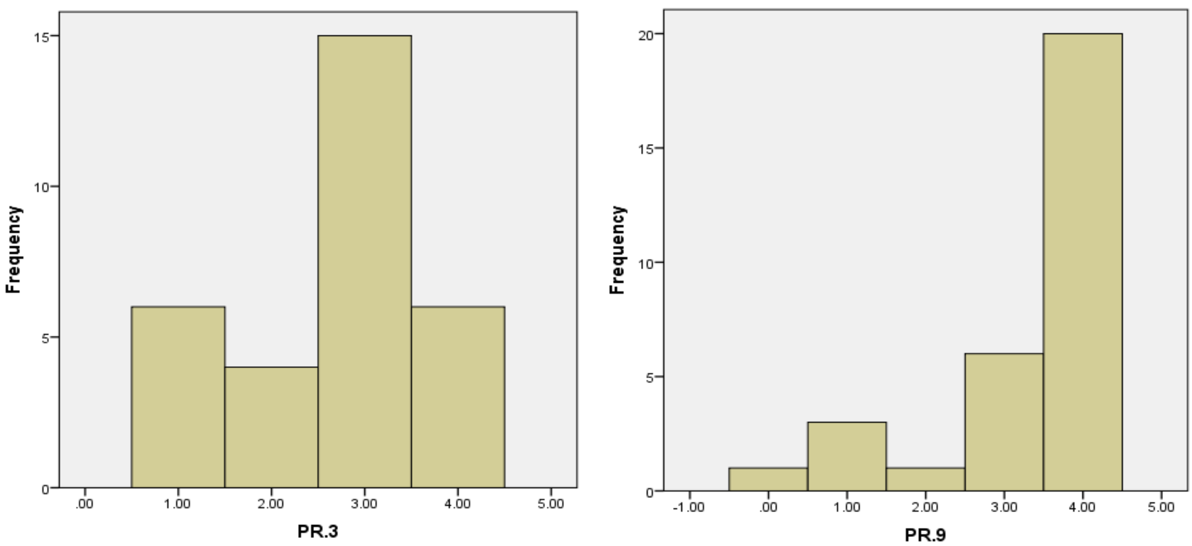


Figure 20: Frequency Analysis of "PR.3" risk impact on BIM's cost reduction (left) and "PR.9" risk impact on BIM's collaboration enhancement (right)

B- Negatively Skewed Distributions: where the median (midpoint) is shifted towards the right side (negative direction) of the neutral point on the data scale. This type means that a BIM risk received an overall negative impact with less levels of agreement than the first type discussed. Two expected instances of this distribution are shown in ***figure-21*** including the impact of "PR.5" BIM learning/training time on its time reduction and the impact of "PR.13" unfamiliarity with BIM's parametric concepts on its collaboration improvement.

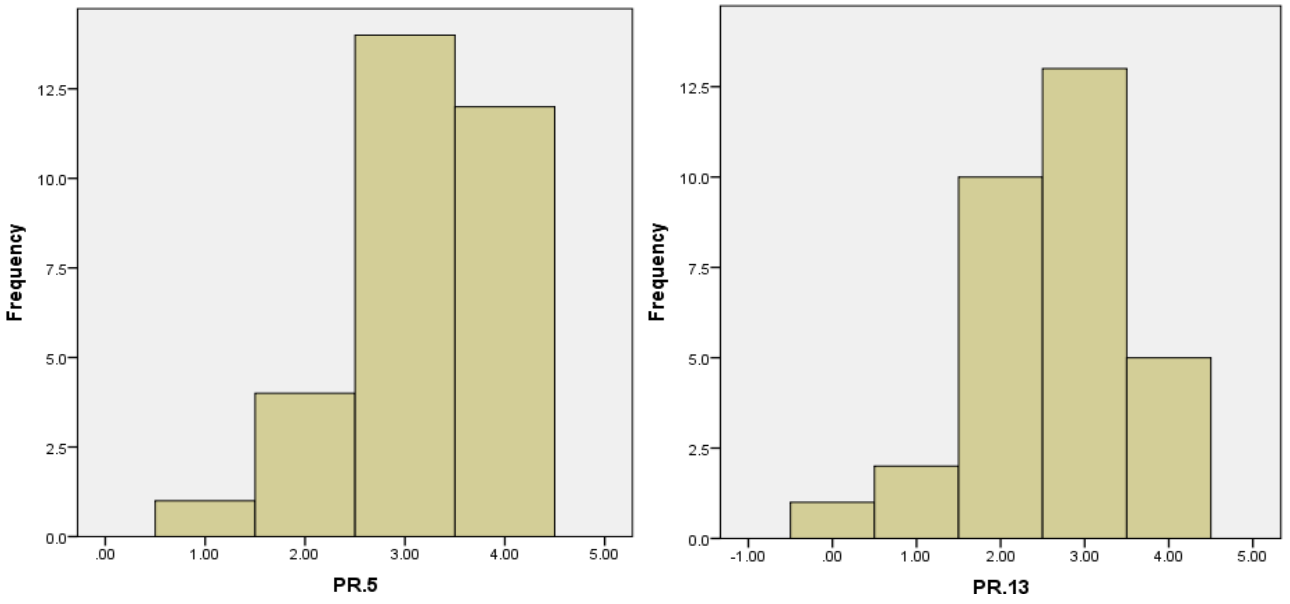


Figure 21: Frequency Analysis of "PR.5" risk impact on BIM's time reduction (left) and "PR.13" risk impact on BIM's collaboration enhancement (right)

However, ***figure-22*** shows that the impact of "PR.8" BIM hardware and software costs on its time reduction has unexpectedly received an overall negative value, this might be because of the respondents' interpretation of the effect that the installation of computers and programs have on time savings.

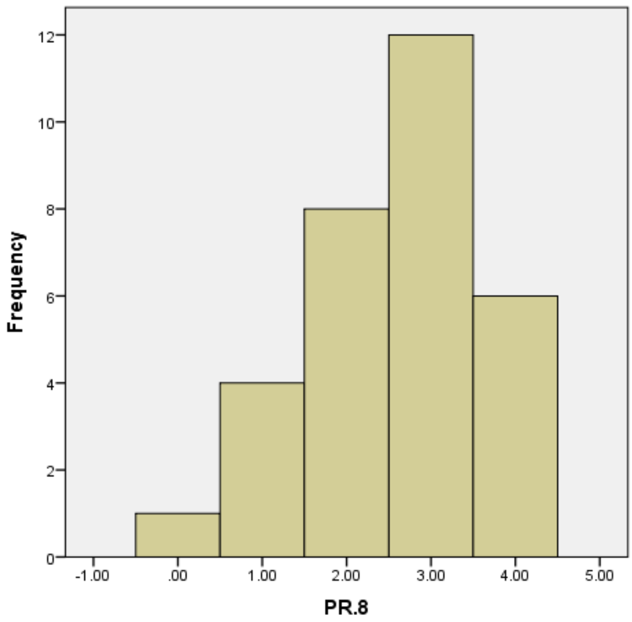


Figure 22: Frequency Analysis of "PR.8" risk impact on BIM's time reduction

C- Geometric Distributions: this is another form of the negatively skewed distribution where the data skewness is more uniform in the negative direction. ***Figure-23*** demonstrates two examples of this type including the impact of "T.2" lack of electronic BIM standards on its collaboration enhancement and the impact of "PR.9" unwillingness of team members to share information on its time reduction.

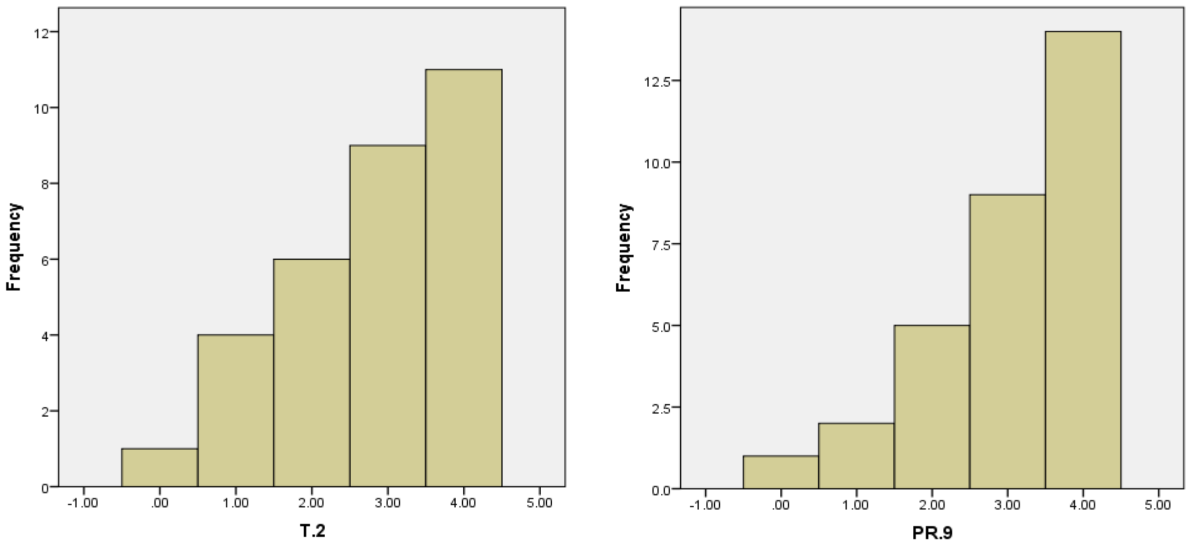


Figure 23: Frequency Analysis of "T.2" risk impact on BIM's collaboration enhancement (left) and "PR.9" risk impact on BIM's time reduction (right)

6.5 Ranking of BIM Risks under BIM Advantages

As mentioned earlier in ***Section 5.3.3***, the data in the "Likert" scale used to measure the impact of 18 BIM risks on three of its advantages is assumed to be continuous, this is why analyzing the weighted means for each BIM risk is valid to reach a ranking of the risks (taking the average weighted means of a five-category scale (from 0 to 4) results in continuous scores out of 4). First, each of the answers in the "Likert" scale was converted into a score (0,1,2,3,4), then the formula given by Finch (2009) in ***figure-24*** was used to calculate the final weighted mean for the BIM risks, this process was repeated for each of BIM's three advantages (cost reduction, time reduction and collaboration improvement).

$$\mu_n = \frac{1}{n}\sum_{i=1}^{n} x_i$$

μ_n = Weighted Mean

n = Number of Respondents

$\sum_{i=1}^{n}$ = Sum

x_i = Rating Score * Frequency of Answers

Figure 24: Weighted Mean Formula (Finch; 2009, p.1)

In addition to the weighted mean, the Severity Index (SI) for each BIM risk was calculated according to the formula by Assaf and Al-Hejji (2006) in ***figure-25***; this can give an indication of the percentage by which the BIM risks affect its three advantages.

$$\text{Severity Index} \quad (\text{S.I.})\ (\%) = \sum a(n/N) * 100/4$$

$\sum$ = Sum a = Rating Score n = Frequency of Answers

N = Number of Respondents

Figure 25: Severity Index Formula (S.I.) (Assaf and Al-Hejji 2006, p.351)

6.5.1 Ranking of Risks under BIM's Cost Reduction

Table-12 below shows the average weighted means as well as the Severity Index for the 18 BIM risks under BIM's cost reduction.

Table 12: Ranking of the BIM Risks under BIM's Cost Reduction

Rank	Code	BIM Risk Factor	Weighted Mean (out of 4)	Severity Index (S.I.)	Standard Deviation	N
1	PR.6	Lack of internal team organization and definition of responsibility of members' model input	3.00	75.00%	0.38	31
2	PR.9	Team members won't share information	2.97	74.19%	0.35	31
3	PR.1	Project team's lack of experience in BIM	2.84	70.97%	0.22	31
4	PR.4	Absence of higher management support for BIM	2.81	70.16%	0.19	31
5	PR.5	Time spent for BIM training/learning	2.71	67.74%	0.09	31
5	PR.12	Recruited or trained BIM people leave their companies	2.71	67.74%	0.09	31
7	PR.2	Costs of training and recruitment	2.68	66.94%	0.06	31
7	PR.3	Other project parties won't adapt BIM because of not knowing its benefits/preferring traditional method	2.68	66.94%	0.06	31
7	T.2	Lack of electronic BIM standards (families, templates...etc)	2.68	66.94%	0.06	31
10	PR.13	Unfamiliarity with BIM parametric concepts (parametric families)	2.65	66.13%	0.03	31
11	PR.8	Cost of upgrading computers, technical support and software licenses	2.61	65.32%	0.01	31
12	T.1	Incompatibility of BIM programs and loss of data	2.55	63.71%	0.07	31
12	PR.10	Project concepts are produced using CAD	2.55	63.71%	0.07	31
12	PR.14	Gap in staff skills in 4D (scheduling) and 5D (cost estimating)	2.55	63.71%	0.07	31
15	PL.2	Lack of legal contracts specifically for BIM	2.35	58.87%	0.27	31
15	PR.7	BIM's difficult implementation (It has to come in level by level)	2.35	58.87%	0.27	31
17	PR.11	Time needed to start making the BIM model	2.32	58.06%	0.30	31
18	PL.1	BIM model copyrights are not defined	2.16	54.03%	0.46	31

Interestingly, the BIM risks with the highest impact on its cost reduction are not direct cost challenges and are instead related to internal team challenges such as lack of experience, sharing of information and team organization which shows that respondents believe these issues have a greater impact on cost reduction than the direct costs represented by BIM's training/recruitment costs (coming in 7th place along with two other BIM risks) as well as BIM's software/hardware costs (coming in 11th place). The two Policy-domain risks came at the bottom part of the ranking with the lowest risk being "Undefined ownership of the BIM model".

Table 13: Statistics Summary for Weighted Means of BIM Risks under Cost Reduction

	Mean	Minimum	Maximum	Range	Maximum/Minimum	Variance	N of Items
Item Means	2.62	2.16	3.00	0.84	1.39	0.049	18

In summary, BIM's cost reduction received weighted mean values from **2.16** to **3.00** out of 4 (average of **2.62**) with a variance of **0.049** (smallest of all BIM advantages), this indicates respondents' assumption that the 18 risks of BIM somehow affect its cost reduction in a similar manner, the two risks closest to the average mean are related to BIM parametric families as well as hardware/software costs.

6.5.2 Ranking of Risks under BIM's Time Reduction

The average weighted means and the Severity Indices for the 18 BIM risks under BIM's time reduction are shown in ***table-14*** below.

Table 14: Ranking of the BIM Risks under BIM's Time Reduction

Rank	Code	BIM Risk Factor	Weighted Mean (out of 4)	Severity Index (S.I.)	Standard Deviation	N
1	PR.5	Time spent for BIM training/learning	3.19	79.84%	0.49	31
2	PR.9	Team members won't share information	3.06	76.61%	0.36	31
3	PR.6	Lack of internal team organization and definition of responsibility of members' model input	3.00	75.00%	0.29	31
4	T.2	Lack of electronic BIM standards (families, templates...etc)	2.97	74.19%	0.26	31
5	PR.3	Other project parties won't adapt BIM because of not knowing its benefits/preferring traditional method	2.87	71.77%	0.16	31
6	PR.1	Project team's lack of experience in BIM	2.84	70.97%	0.13	31
6	PR.4	Absence of higher management support for BIM	2.84	70.97%	0.13	31
6	PR.12	Recruited or trained BIM people leave their companies	2.84	70.97%	0.13	31
9	PR.2	Costs of training and recruitment	2.77	69.35%	0.07	31

Table 14 (continued): Ranking of the BIM Risks under BIM's Time Reduction

Rank	Code	BIM Risk Factor	Weighted Mean (out of 4)	Severity Index (S.I.)	Standard Deviation	N
10	PR.14	Gap in staff skills in 4D (scheduling) and 5D (cost estimating)	2.65	66.13%	0.06	31
11	T.1	Incompatibility of BIM programs and loss of data	2.61	65.32%	0.09	31
12	PR.7	BIM's difficult implementation (It has to come in level by level)	2.58	64.52%	0.13	31
12	PR.8	Cost of upgrading computers, technical support and software licenses	2.58	64.52%	0.13	31
14	PR.10	Project concepts are produced using CAD	2.52	62.90%	0.19	31
15	PR.11	Time needed to start making the BIM model	2.45	61.29%	0.26	31
15	PR.13	Unfamiliarity with BIM parametric concepts (parametric families)	2.45	61.29%	0.26	31
17	PL.2	Lack of legal contracts specifically for BIM	2.35	58.87%	0.35	31
18	PL.1	BIM model copyrights are not defined	2.16	54.03%	0.55	31

In contrast with BIM's cost reduction, its time reduction advantage received the highest impact from a direct time challenge (BIM's training/education time), other than the common pattern of the internal team challenges, the lack of electronic BIM standards was unexpectedly among the risks with the highest impact which shows that the respondents consider the added time in collecting information from different BIM standards and creating custom BIM families is a significant barrier for its time reduction feature, it's also important to note that the initial added time needed to create the BIM model indicated by Bryde, Broquetas and Volm (2013) and Gray et al. (2013) in the literature received the third lowest impact on BIM's time reduction, furthermore BIM's Policy-domain risks received the lowest impacts once again.

Table 15: Statistics Summary for Weighted Means of BIM Risks under Time Reduction

	Mean	Minimum	Maximum	Range	Maximum/Minimum	Variance	N of Items
Item Means	2.71	2.16	3.19	1.03	1.48	0.073	18

BIM's time reduction received weighted means from **2.16** to **3.19** out of 4 (average of **2.71**) with a variance of **0.073** (average of the three BIM advantages), BIM's hardware/software expenses came closest to the average mean again along with the gap in staff skills in 4D and 5D modelling.

6.5.3 Ranking of Risks under BIM's Collaboration Improvement

Finally, the weighted means and Severity Indices under BIM's collaboration improvement are shown in ***table-16*** below.

Table 16: Ranking of the BIM Risks under BIM's Collaboration Improvement

Rank	Code	BIM Risk Factor	Weighted Mean (out of 4)	Severity Index (S.I.)	Standard Deviation	N
1	PR.9	Team members won't share information	3.32	83.06%	0.69	31
2	PR.1	Project team's lack of experience in BIM	3.10	77.42%	0.46	31
3	PR.6	Lack of internal team organization and definition of responsibility of members' model input	2.97	74.19%	0.33	31
4	PR.12	Recruited or trained BIM people leave their companies	2.90	72.58%	0.27	31
5	PR.3	Other project parties won't adapt BIM because of not knowing its benefits/preferring traditional method	2.87	71.77%	0.24	31
6	T.2	Lack of electronic BIM standards (families, templates...etc)	2.81	70.16%	0.17	31
7	PR.2	Costs of training and recruitment	2.68	66.94%	0.04	31
8	PR.13	Unfamiliarity with BIM parametric concepts (parametric families)	2.61	65.32%	0.02	31
9	PR.5	Time spent for BIM training/learning	2.58	64.52%	0.05	31
10	PR.14	Gap in staff skills in 4D (scheduling) and 5D (cost estimating)	2.55	63.71%	0.09	31
11	PR.4	Absence of higher management support for BIM	2.52	62.90%	0.12	31
11	PR.7	BIM's difficult implementation (It has to come in level by level)	2.52	62.90%	0.12	31
11	PR.10	Project concepts are produced using CAD	2.52	62.90%	0.12	31
14	T.1	Incompatibility of BIM programs and loss of data	2.45	61.29%	0.18	31
15	PL.2	Lack of legal contracts specifically for BIM	2.42	60.48%	0.22	31
16	PR.11	Time needed to start making the BIM model	2.26	56.45%	0.38	31
17	PL.1	BIM model copyrights are not defined	2.23	55.65%	0.41	31
18	PR.8	Cost of upgrading computers, technical support and software licenses	2.13	53.23%	0.51	31

As expected, BIM's collaboration improvement received the three highest impacts from team-related challenges whereas trained/recruited BIM employees moving to other companies came in 4th place, this indicates that the process of hiring new employees instead affects the collaboration process as the previously established harmony among the team is lost, respondents also agreed that the collaboration improvement is affected when other stakeholders do not adopt BIM. Along with BIM's Policy-domain risks, the time need to make the initial BIM model as well as BIM's software/hardware expenses received the lowest impact weights on BIM's collaboration enhancement.

Table 17: Statistics Summary for Weighted Means of BIM Risks under Collaboration Improvement

	Mean	Minimum	Maximum	Range	Maximum/Minimum	Variance	N of Items
Item Means	2.63	2.13	3.32	1.19	1.56	0.097	18

The advantage of improving collaboration by BIM received weighted means from **2.13** to **3.32** out of 4 (average of **2.63**) with a variance of **0.097** (highest of all BIM advantages) meaning that the respondents feel that the 18 risks of BIM have more different impacts on BIM's collaboration enhancement than the other two advantages. The risks closest to the average mean varied between cost, time and skill/knowledge challenges for team members.

6.6 Ranking of BIM Risks under Demographic Groups

This section discusses how the BIM risks were rated based on the different demographic backgrounds of the respondents. The tables showing the full results for each demographic group are list in ***Appendix-B***.

6.6.1 Nature of Organization Ranking:

BIM's Cost Reduction

As shown in ***table-38***, the average mean for the ratings of consultants and contractors under BIM's cost reduction is almost equal (2.63 and 2.61 respectively). Although both groups agreed on the impact of "PR.9" team members' unwillingness to share information, they had different views on a number of risks including "PR.3" other parties not adopting BIM (rated higher by consultants) which proves the finding by Manning and Messner (2008), also "PL.1" copyrights of BIM models are not defined (rated higher by contractors), "PR.8" BIM hardware/software costs (rated higher by consultants) which proves the finding by Jones (2015) that contractors are more optimistic regarding the cost reduction of BIM and finally "PR.12" recruited/trained BIM staff leaving their companies (rated higher by contractors).

BIM's Time Reduction

As for BIM's time saving advantage, ***table-39*** shows that the average rating of consultants are slightly higher than contractors which contradicts with the outcome of the survey by Jones (2015) suggesting that consultants are more optimistic regarding BIM's time reduction. The risk that both groups agreed on most is "PR.7" BIM's implementation has to come in levels. On the other hand, they had different ratings for the impact of “PR.2” BIM’s training/recruitment costs on its time reduction (rated significantly higher by contractors) although it would not make sense for the costs of BIM training to have an impact on its time reduction, this might indicate that contractors’ major barrier for BIM’s time savings is the overall training and recruitment process (top three highest rated risks by contractors are time and cost of BIM training/employment and recruited BIM staff leaving their companies which will require additional training and recruitment). Other risks that had significant difference in ratings are “PR.1” the team’s lack of BIM experience and “PR.10” production of project concepts in CAD (rated higher by consultants) which shows that the added time from producing the concept stage of the project in CAD is mainly affecting the following design stages rather than the construction stage.

BIM’s Collaboration Improvement

The results for this advantage in ***table-40*** suggest that the average ratings for consultants and contractors are very close, they show that the two groups agreed on the significant impact of “PR.9” reluctance of team members to share information on BIM’s collaboration enhancement, they also met on the impact of “PR.14” missing staff skills in 4D and 5D BIM modelling. On the other hand, consultants and contractors had significantly different ratings for “PR.2” training/recruitment costs (rated higher by contractors) which might support the suggestion for the previous advantage that contractors have an overall significant perception of the process of BIM employment/training, both groups also rated “PR.1” lack of team experience in BIM differently (rated higher by consultants) which concludes that consultants rated this challenge higher for all three BIM advantages. Finally, consultants rated the risk “PR.4” lack of higher management support for BIM noticeably higher than contractors.

6.6.2 Size of Organization Ranking:

BIM’s Cost Reduction

As indicated in ***table-41***, the average ratings for respondents from small and large companies is nearly equal (2.63 and 2.58 correspondingly). Respondents from small firms rated the impact of “PR.2” training/recruitment costs higher which agrees with the suggestions in the literature that smaller organizations perceive the impact of direct costs of BIM implementation higher than larger ones. The risk with the highest variance among both groups is “PR.1” lack of team BIM experience (rated higher by large organizations).

BIM's Time Reduction

The average impact of BIM challenges on its time saving advantage in ***table-42*** for respondents in small organizations is higher than those in larger organizations (2.94 and 2.63 respectively). The two groups agreed most on the impact of "PR.12" trained/recruited BIM employees leaving their companies. The risks with the biggest difference between the two groups are "T.1" incompatibility of BIM programs and "PR.6" lack of internal team organization and definition of liabilities (rated higher by smaller organizations).

BIM's Collaboration Improvement

Respondents from small and large organizations had similar average ratings for this advantage (2.76 and 2.59 correspondingly) which doesn't support the assumption that respondents in larger organizations would rate the impact of BIM risks on collaboration higher than those in smaller organizations due to the expected collaboration issues in a larger working place. Furthermore, the results in ***table-43*** show that the risks that shared the top ranks among both groups are "PR.9" poor team information sharing and "PR.1" lack of BIM team expertise. The results do not show any significant difference in the ratings of the two groups.

6.6.3 Position Ranking:

When it comes to the ratings of respondents based on their roles in their organizations, the architects will represent one group while the other group consisting of draftsmen, engineers and BIM/design managers will be referred to as "non-architects".

BIM's Cost Reduction

The average ratings for architects under this advantage are slightly lower than non-architects (2.42 and 2.71 respectively). ***Table-44*** suggest that both groups agreed most on the impact of "PR.4" missing higher management support on BIM's cost savings; they also shared a similar rating for "PR.6" lack of team organization and liability definition. However architects and non-architects had considerably different ratings for a number of risks including "PR.1" lack of BIM team experience (rated higher by non-architects) which comes in conjunction with the finding by Jones (2015) that engineers perceive the lack of skills in using advanced technologies more significantly than architects. Interestingly, two risks received average ratings lower and higher than the neutral point between both groups including "PR.7" required levels for BIM implementation and "PR.10" production of concepts in CAD (rated lower by architects).

BIM's Time Reduction

Both groups had similar average ratings for BIM's time saving advantage (architects' ratings are a bit higher), they both agreed most on the impact of "PR.5" BIM training/education time and "PR.4" absence of upper management support. Moreover, ***table-45*** shows that architect and non-architects still disagreed on the impact of "PR.1" lack of team BIM experience (this time rated higher by architects), they also had different opinions on the impact of "PR.6" lack of internal team organization and responsibility definition (rated higher by architects).

BIM's Collaboration Improvement

The ratings for both groups under this BIM advantage are close once again (2.58 for architects and 2.66 for non-architects). The two groups agreed most on the impact of "PR.9" unwillingness of team members to share information and disagreed most on the impact of "PR.4" lack of higher management support (rated higher by architects) as shown in ***table-46***.

6.6.4 General Experience Ranking:

Respondents with less than 5 years of experience will be referred to as "less experienced" and those with more than 5 years will be called "experienced".

BIM's Cost Reduction

The average rating for experienced respondents in ***table-47*** is higher than that for less experienced ones (2.77 and 2.43 respectively). Both groups agreed most on the impact of "PR.2" training/recruitment costs. However, experienced respondents did have considerably higher ratings for "PR.10" doing project concepts in CAD, "PR.4" absence of higher management support and "PR.1" team's lack of BIM expertise.

BIM's Time Reduction

Experienced respondents also had a slightly higher average rating for this BIM benefit than less experienced ones (2.75 and 2.66 correspondingly). The numbers in ***table-48*** suggest that both groups agreed most on the impact of "PR.9" reluctance of team members to share information and disagreed most on the impact of "PR.4" lack of higher management support (rated higher by experienced respondents).

BIM's Collaboration Improvement

Similarly, the third advantage of BIM witnessed higher ratings from experienced respondents as shown in ***table-49***. Both groups shared similar top rankings including "PR.9" unwillingness of team members to share information and "PR.1" lack of team experience in BIM. Experienced respondents had noticeably higher ratings than less experienced ones for "PL.2" lack of legal contracts specifically for BIM and "PR.10" project concepts are produced in CAD.

6.6.5 BIM Experience Ranking:

The ratings for each of the three categories in this demographic group (no BIM experience, less than 5 years and more than 5 years) were studied and the impacts that seem to have a pattern of increasing or decreasing with BIM experience are highlighted.

BIM's Cost Reduction

The results in ***table-50*** show that the average ratings for this advantage are slightly increasing with more BIM experience (2.53 for respondents with no experience, 2.61 for those with less than 5 years and 2.65 for those with more than 5 years). The risk that the three categories agreed on most is "PR.3" other stakeholders not adopting BIM. Similar to the general experience rankings, the risk that received significantly increasing ratings with more BIM experience is "PR.10" project concepts are done in CAD.

BIM's Time Reduction

In contrast with the cost reduction advantage, the average ratings for the time reduction advantage in ***table-51*** are slightly decreasing with more BIM experience (2.86 for respondents with no experience, 2.66 for those with less than 5 years and 2.62 for those with more than 5 years). The risk that the three categories agreed on most is "PR.10" production of concepts in CAD. On the other hand, the risk that received considerably decreasing ratings with more BIM experience is "PR.14" gaps in staff skills in 4D and 5D BIM modelling which might be understandable as more experienced BIM people would either have more experience in 4D and 5D or would perceive the limitations of these two BIM uses more maturely.

BIM's Collaboration Improvement

The third and final advantage of BIM received average ratings that are not uniformly increasing nor decreasing with BIM experience (2.53 for respondents with no experience, 2.72 for those with less than 5 years and 2.63 for those with more than 5 years). The ratings in ***table-52*** show that the most agreed on risks are "PR.1" lack of team experience in BIM and "PR.7" required levels for BIM incorporation. The risks that had clearly increasing ratings with more BIM experience are "PR.6" lack of internal team organization and responsibility definition and "PR.9" unwillingness of team members to share information.

6.7 Chapter Conclusion:

To summarize what has been presented in this chapter, first the distributions of the demographic groups in the survey sample and their expected impact on the results were both explained, then the values of Cronbach's Alpha were presented to test the validity of the answers, after that the answer frequencies for some of the BIM risks were analyzed and finally the risks were ranked according to their impact on BIM's advantages and based on the different demographic classes of the respondents.

CHAPTER 7: BIM RISKS VARIANCE ANALYSIS:

7.1 Chapter Introduction:

The main goal of this chapter is to determine any difference in respondents' ratings of the impact of BIM risks on its advantages based on their professional backgrounds (role, company size/type, experience), an example is comparing the means that BIM risks received for its cost reduction advantage under each of the BIM experience categories, this would allow the detection of any significant difference between the ratings of experienced and less experienced respondents. As explained in ***Section 5.3.6***, the tests that will be used to examine the research hypothesis are dictated by the types of variables in this study, therefore two tests will be used in SPSS software for variance analysis: an Independent T-Test (for demographic classes with two groups) and a One-way ANOVA test (for classes with more than two groups) where the means of the respondents' impact ratings are compared against their demographic groups. The criterion for testing the research and null hypotheses in the conceptual model is determined by the p-values (Sig) resulting from the two previously mentioned tests, although the process of finding those values is different from one test to another, the level of significance for the final p-values is assumed to be **0.05** (conventionally 0.05, 0.01 or 0.001).

H_0: **Null Hypothesis** ($p > 0.05$) – There is no significant difference between the respondents' rating of the impact of BIM risks on its advantages.

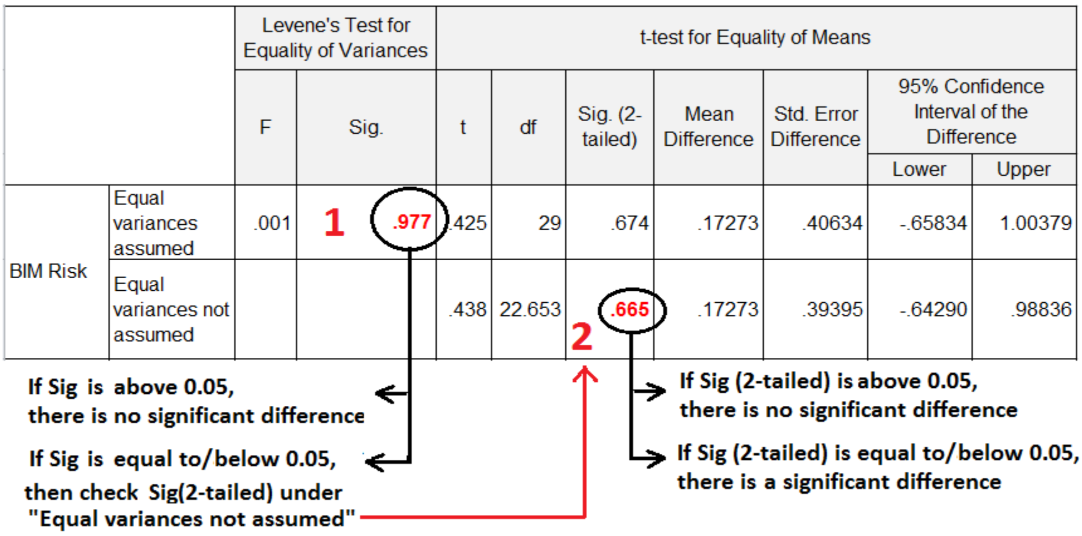
H_1: **Research Hypothesis** ($p \leq 0.05$) – There is a significant difference between the respondents' rating of the impact of BIM risks on its advantages.

Figure 26: Criterion for Testing Null and Research Hypotheses in Variance Tests

7.2 Independent T-Test:

7.2.1 Description:

This type of variance test is used to examine the variance in the mean scores of a certain element (rating impact) under different groups of the same demographic class, this test is only used when the demographic classes have two categories; this includes: Nature and Size of Organization, Position and General Experience. As explained in ***figure-27*** in the following page, the process of testing the above mentioned hypotheses in an independent t-test starts by looking at the "***Sig***" value of each BIM risk under "***Levene's Test for Equality of Variances***", if the value is above 0.05 then the null hypothesis is proved and thus there is no significant difference in respondents' ratings while if it is equal to or below 0.05 then the ***sig (2-tailed)*** value for "***Equal variances not assumed***" must be examined, if the sig (2-tailed) value is above 0.05 then the null hypothesis is confirmed and there is no significant difference is respondents' ratings however if it is equal to or below 0.05 then the research hypothesis is verified and there is a significant difference in the ratings.



		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
BIM Risk	Equal variances assumed	.001	1 .977	.425	29	.674	.17273	.40634	-.65834	1.00379
	Equal variances not assumed			.438	22.653	2 .665	.17273	.39395	-.64290	.98836

Figure 27: Hypothesis Testing through Independent T-Test

7.2.2 Results:

The comprehensive results of the independent t-test are presented in ***Appendix-C***; only the significant results will be shown in this section.

7.2.2A Nature of Organization Group:

The first group under examination represents the type of company and contains two categories (Consultant and Contractor), the results of the independent t-tests are:

BIM's Cost Reduction:

Even though two BIM risks were initially suspected to have variance in ratings, the independent t-test for this advantage in ***table-18*** showed that there was no significant difference in the ratings of PR.8 for consultants (M=2.85, SD=0.813) and contractors (M=2.18, SD=1.328) conditions; t (14.2) = 1.52, p = 0.151. Similarly, there was no significant difference in PR.12 for consultants (M=2.5, SD=1.192) and contractors (M=3.09, SD = 0.700) conditions; t (28.8) = -1.74, p = 0.093.

Table 18: Independent T-Test for the Impact of “PR.8” & “PR.12” Risks on BIM’s Cost Reduction (Type of Organization Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference: Lower	Upper
PR.8	Equal variances assumed	5.503	.026	1.745	29	.092	.66818	.38298	-0.11510	1.45146
	Equal variances not assumed			1.520	14.226	.151	.66818	.43972	-0.27353	1.60989
PR.12	Equal variances assumed	5.683	.024	-1.501	29	.144	-.59091	.39376	-1.39623	.21441
	Equal variances not assumed			-1.737	28.786	.093	-.59091	.34012	-1.28675	.10494

BIM’s Time Reduction:

As shown in ***table-19***, there is a significant difference in the ratings of PR.2 (costs of BIM training/recruitment) on BIM’s time reduction for consultants (M=2.5, SD=1.05) and contractors (M=3.27, SD = 0.647) conditions; t (28.5) = -2.53, p = 0.017. As explained in ***section 6.6.1***, the interpretation of this finding is that contractors perceive a large impact of the overall process of BIM recruitment and training on its advantages rather than the direct impact of the costs of training/recruitment on BIM’s time reduction, this can be supported by the fact that the top three rated risks for contractors are related to training and recruitment.

Table 19: Independent T-Test for the Impact of “PR.2” Risk on BIM’s Time Reduction (Type of Organization Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference: Lower	Upper
PR.2	Equal variances assumed	4.800	.037	-2.209	29	.035	-.77273	.34980	-1.48814	-.05732
	Equal variances not assumed			-2.530	28.504	.017	-.77273	.30542	-1.39785	-.14761

BIM's Collaboration Improvement:

Similar to the time reduction advantage, the results in ***table-20*** show that there is a significant difference in the ratings of PR.2 (costs of BIM training/recruitment) on BIM's collaboration enhancement for consultants (M=2.25, SD=1.164) and contractors (M=3.45, SD = 0.522) conditions; t (28.26) = -3.959, p = 0.000, this supports the explanation under BIM's time reduction suggesting that contractors have an overall large perception of the impact of BIM's training and recruitment process on all of its advantages. On the other hand, two other risks were suspected to have variance in ratings, however it appears that there is no significant difference in the ratings of PR.4 for consultants (M=2.8, SD=1.005) and contractors (M=2.0, SD = 1.612) conditions; t (14.39) = 1.494, p = 0.157 as well as the ratings of PR.6 for consultants (M=3.15, SD=1.09) and contractors (M=2.63, SD = 1.56) conditions; t (15.45) = 0.966, p = 0.349.

Table 20: Independent T-Test for the Impact of "PR.2", "PR.4" & "PR.6" Risks on BIM's Collaboration Improvement (Type of Organization Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
PR.2	Equal variances assumed	4.376	.045	-3.238	29	.003	-1.20455	.37198	-1.96533	-.44376
	Equal variances not assumed			-3.959	28.259	.000	-1.20455	.30423	-1.82748	-.58161
PR.4	Equal variances assumed	9.595	.004	1.707	29	.098	.80000	.46864	-.15848	1.75848
	Equal variances not assumed			1.494	14.386	.157	.80000	.53562	-.34591	1.94591
PR.6	Equal variances assumed	4.694	.039	1.074	29	.292	.51364	.47837	-.46473	1.49200
	Equal variances not assumed			0.966	15.451	.349	.51364	.53149	-.61634	1.64361

7.2.2B Size of Organization Group:

This demographic group also contains two categories under the size of the company (Less than 100 Employees and More than 100 Employees).

BIM's Cost Reduction:

The ratings of BIM's risks under this advantage in ***table-21*** show that two risks had initially received p-values lower than 0.05, however it seems that there is no significant difference in the ratings of PR.9 for small organizations (M=2.875, SD=1.246) and large organizations (M=3.0, SD = 0.904) conditions; t (9.696) = -0.261, p = 0.800 as well as the ratings of PR.12 for small organizations (M=2.25, SD=1.388) and large organizations (M=2.87, SD = 0.92) conditions; t (9.23) = -1.175, p = 0.269.

Table 21: Independent T-Test for the Impact of "PR.9" & "PR.12" Risks on BIM's Cost Reduction (Size of Organization Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PR.9	Equal variances assumed	4.486	**.043**	-0.305	29	.762	-.12500	.40958	-.96268	0.71268
	Equal variances not assumed			-0.261	9.696	**.800**	-.12500	.47934	-1.19760	0.94760
PR.12	Equal variances assumed	4.270	**.048**	-1.435	29	.162	-.61957	.43190	-1.50290	.26377
	Equal variances not assumed			-1.175	9.230	**.269**	-.61957	.52711	-1.80746	.56833

BIM's Time Reduction:

On the other hand, this advantage of BIM received one p-value lower than 0.05, though ***table-22*** shows that there is no significant difference in the ratings of PR.2 for small organizations (M=2.5, SD=1.31) and large organizations (M=2.87, SD = 0.87) conditions; t (9.24) = -0.743, p = 0.476.

Table 22: Independent T-Test for the Impact of "PR.2" Risk on BIM's Time Reduction (Size of Organization Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PR.2	Equal variances assumed	4.519	**.042**	-0.907	29	.372	-.36957	.40768	-1.20337	.46424
	Equal variances not assumed			-0.743	9.240	**.476**	-.36957	.49710	-1.48965	.75052

BIM's Collaboration Improvement:

The findings under this advantage in ***table-23*** suggest that one BIM risk received p-value lower than 0.05, however it shows that there is no significant difference in the ratings of PR.4 for small organizations (M=2.875, SD=0.991) and large organizations (M=2.391, SD = 1.373) conditions; t (17.05) = 1.069, p = 0.300.

Table 23: Independent T-Test for the Impact of "PR.4" Risk on BIM's Collaboration Improvement (Size of Organization Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
PR.4	Equal variances assumed	4.306	.047	.913	29	.369	.48370	.53001	-.60030	1.56769
	Equal variances not assumed			1.069	17.050	.300	.48370	.45248	-.47075	1.43814

7.2.2C Position Group:

This group contains two different categories under the role in organization (Architect and Other "Engineer, Draftsman and BIM/Design Manager").

BIM's Cost Reduction:

There is only one BIM risk under this advantage in ***table-24*** with a p-value less than 0.05; yet the results show that there is no significant difference in the ratings of PR.12 for architects (M=2.1, SD=1.197) and non-architects (M=3.0, SD = 0.894) conditions; t (13.976) = -2.113, p = 0.053.

Table 24: Independent T-Test for the Impact of "PR.12" risk on BIM's Cost Reduction (Position Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
PR.12	Equal variances assumed	4.247	.048	-2.347	29	.026	-.90000	.38355	-1.68445	-.11555
	Equal variances not assumed			-2.113	13.976	.053	-.90000	.42594	-1.81371	.01371

BIM's Time Reduction:

The findings under this BIM advantage in ***table-25*** show three risks with p-values lower than 0.05. Furthermore, it appears that there is no significant difference in the ratings of PR.1 for architects (M=3.3, SD=0.949) and non-architects (M=2.62, SD = 1.36) conditions; t (24.6) = 1.614, p = 0.119, the ratings of PR.2 for architects (M=2.3, SD=1.159) and non-architects (M=3.0, SD = 0.837) conditions; t (13.64) = -1.709 p = 0.110, and the ratings for PR.14 for architects (M=3.0, SD=0.943) and non-architects (M=2.48, SD = 1.4) conditions; t (25.29) = 1.227, p = 0.231

Table 25: Independent T-Test for the Impact of "PR.1", "PR.2" & "PR.14" Risks on BIM's Time Reduction (Position Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PR.1	Equal variances assumed	4.834	**.036**	1.422	29	.166	0.68095	.47888	-.29848	1.66038
	Equal variances not assumed			1.614	24.613	**.119**	0.68095	.42188	-.18862	1.55052
PR.2	Equal variances assumed	5.118	**.031**	-1.920	29	.065	-.70000	.36450	-1.44548	.04548
	Equal variances not assumed			-1.709	13.639	**.110**	-.70000	.40961	-1.58071	.18071
PR.14	Equal variances assumed	4.288	**.047**	1.068	29	.294	.52381	.49036	-.47910	1.52672
	Equal variances not assumed			1.227	25.289	**.231**	.52381	.42698	-.35507	1.40268

BIM's Collaboration Improvement:

Similarly, the data in ***table-26*** shows that four risks received "Sig" values less than 0.05, yet all risks had no significant difference in ratings including PL.1 for architects (M=2.3, SD=0.823) and non-architects (M=2.19, SD = 1.4) conditions; t (27.4) = 0.273, p = 0.787, PR.4 for architects (M=3.0, SD=0.666) and non-architects (M=2.29, SD = 1.454) conditions; t (29) = 1.875, p = 0.071, PL.2 for architects (M=2.1, SD=0.738) and non-architects (M=2.57, SD = 1.21) conditions; t (26.9) = -1.34, p = 0.192 and PR.8 for architects (M=1.9, SD=0.57) and non-architects (M=2.24, SD = 1.26) conditions; t (29) = -1.029, p = 0.312

Table 26: Independent T-Test for the Impact of "PR.1", "PR.4", "PL.2" & "PR.8" Risks on BIM's Collaboration Improvement (Position Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
PL.1	Equal variances assumed	6.307	.018	0.228	29	.821	.10952	.48040	-0.87301	1.09205
	Equal variances not assumed			0.273	27.445	.787	.10952	.40150	-0.71366	.93271
PR.4	Equal variances assumed	20.490	.000	1.472	29	.152	.71429	.48540	-.27846	1.70703
	Equal variances not assumed			1.875	28.998	.071	.71429	.38095	-.06485	1.49342
PL.2	Equal variances assumed	4.896	.035	-1.132	29	.267	-.47143	.41628	-1.32282	.37996
	Equal variances not assumed			-1.340	26.898	.192	-.47143	.35190	-1.19359	.25073
PR.8	Equal variances assumed	6.983	.013	-.804	29	.428	-.33810	.42034	-1.19778	.52159
	Equal variances not assumed			-1.029	28.981	.312	-.33810	.32857	-1.01012	.33393

7.2.2D Experience Group:

This group contains two categories under professional expertise (Less than 5 years and More than 5 years of experience).

BIM's Cost Reduction:

Two of the 18 BIM risks under this advantage in ***table-27*** received p-values less than 0.05, it appears that there is no significant difference in the ratings of PR.3 for less experienced respondents (M=2.57, SD=1.22) and more experienced ones (M=2.76, SD = 0.831) conditions; t (22.175) = -0.503, p = 0.620, however there seems to be a significant difference in the ratings of PR.10 (execution of project concepts in CAD) for less experienced respondents (M=2.0, SD=1.30) and more experienced ones (M=3.0, SD = 0.79) conditions; t (20.565) = -2.519, p = 0.020. The assumed reason behind the experienced respondents' higher ratings for this risk is because of the higher experience they have in the traditional CAD method as compared to professionals with less experience, meaning that experienced respondents understand the implications of transferring a project from CAD to BIM more than the less experienced ones.

Table 27: Independent T-Test for the Impact of "PR.3" & "PR.10" Risks on BIM's Cost Reduction (Experience Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference: Lower	Upper
PR.3	Equal variances assumed	5.560	.025	-0.522	29	.605	-.19328	.37004	-.95010	0.56355
	Equal variances not assumed			-0.503	22.175	.620	-.19328	.38394	-.98915	0.60260
PR.10	Equal variances assumed	4.384	.045	-2.638	29	.013	-1.00000	.37911	-1.77537	-0.22463
	Equal variances not assumed			-2.519	20.565	.020	-1.00000	.39704	-1.82676	-0.17324

BIM's Time Reduction:

The results under the time reduction advantage show no difference in the ratings of the respondents based on their professional experiences.

BIM's Collaboration Improvement:

Likewise, the values in ***table-28*** indicate no significant difference in the ratings of PL.1 for less experienced respondents (M=2.42, SD=0.938) and more experienced ones (M=2.05, SD = 1.43) conditions; t (27.72) = 0.862, p = 0.396 as well as PR.12 for less experienced respondents (M=2.93, SD=0.616) and more experienced ones (M=2.88, SD = 1.11) conditions; t (25.747) = 0.146, p = 0.885.

Table 28: Independent T-Test for the Impact of "PL.1" & "PR.12" Risks on BIM's Collaboration Improvement (Experience Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference: Lower	Upper
PL.1	Equal variances assumed	4.638	.040	0.828	29	.414	.36975	.44641	-0.54327	1.28277
	Equal variances not assumed			0.862	27.721	.396	.36975	.42884	-0.50908	1.24858
PR.12	Equal variances assumed	5.238	.030	.139	29	.891	.04622	.33303	-0.63490	.72734
	Equal variances not assumed			.146	25.747	.885	.04622	.31582	-0.60328	.69571

7.3 One-Way ANOVA Test:

7.3.1 Description:

The test examined in this section is used for the demographic classes with more than two groups; this includes the **BIM experience** class which has three groups (no experience, less than 5 years and more than 5 years). The process of testing the null and research hypotheses in the one-way ANOVA test is explained in ***figure-28***, it begins by examining the “Sig” values in the initial ANOVA test, if the value is above 0.05 then the null hypothesis is verified and there is no significant difference in respondents’ ratings while if the Sig value is below 0.05 then a “***Post Hoc***” test must be used, this test uses two examinations ***“Tukey’s”*** and ***“Scheffe’s”*** to confirm any statistical significance for Sig values equal to or lower than 0.05.

		Sum of Squares	df	Mean Square	F	Sig.
BIM Risk	Between Groups	2.108	2	1.054	.920	.410
	Within Groups	32.085	28	1.146		
	Total	34.194	30			

If "Sig" value is above 0.05, there is no significant difference

If "Sig" value is equal to/below 0.05, then check Post Hoc test (Tukey's)

Figure 28: Hypothesis Testing through One-Way ANOVA Test

7.3.2 Results:

The full tables indicating the results of the One-Way ANOVA test for the impact of BIM risks on its advantages are shown in ***Appendix D***.

7.3.2A BIM Experience Group:

This group contains three categories under BIM expertise (No experience, Less than 5 years and More than 5 years). As shown in ***table 29***, all three advantages of BIM received ratings with Sig values higher than 0.05, this means that the Null Hypothesis is proved and that there is **no significant difference** in respondents’ ratings based on their BIM experiences.

Table 29: "Sig" Values of One-Way ANOVA Test for BIM Experience Group

BIM Risk	Sig. Value		
	BIM's Cost Reduction	BIM's Time Reduction	BIM's Collaboration Improvement
PR.1	0.410	0.855	0.267
T.1	0.944	0.588	0.808
PL.1	0.305	0.606	0.302
PR.2	0.847	0.899	0.404
PR.3	0.740	0.372	0.739
PR.4	0.469	0.267	0.549
PL.2	0.391	0.505	0.989
PR.5	0.313	0.260	0.961
T.2	0.695	0.555	0.915
PR.6	0.592	0.817	0.526
PR.7	0.447	0.364	0.784
PR.8	0.809	0.797	0.789
PR.9	0.665	0.678	0.140
PR.10	0.121	0.981	0.553
PR.11	0.806	0.334	0.603
PR.12	0.656	0.674	0.186
PR.13	0.565	0.548	0.469
PR.14	0.548	0.276	0.295

7.4 Chapter Conclusion:

This chapter illustrated two types of tests to determine any possible variance in respondents' ratings of the impact of BIM risks on its three advantages based on their demographic groups, the first investigation is an independent t-test which is used when the tested demographic group has only two categories (type and size of organization, position and professional experience) while the second examination is a one-way ANOVA test used when the demographic group has more than two categories (BIM experience). The main findings are the larger perceptions that contractors have of the impact of BIM's training/recruitment process on its three advantages as compared to consultants; the second finding is that experienced professionals have a higher perception of the impact of transferring the project from CAD concept to BIM on the cost reduction advantage of BIM as compared to less experienced respondents.

CHAPTER 8: BIM RISKS FACTOR ANAYSIS:

8.1 Chapter Introduction:

This chapter attempts to find a common theme among the 18 risks of BIM that were presented in the questionnaire, the reason behind this is to reduce the number of risks and eliminate any unnecessary factors. The factor analysis procedure is a Principal component analysis (PCA) which begins by a KMO & Bartlett test to check if the sample is valid for factor analysis, after that a total variance test indicates the number of risk components with significant correlations, then a rotated component matrix highlights how the BIM risks are put together under new latent groups, finally the reliability of the resulted risk components is tested to confirm their validity.

8.2 Factor Analysis Process:

8.2.1 KMO & Bartlett Test:

The Kaiser-Meyer-Olkin (KMO) is a test used to measure the adequacy of the sample for factor analysis, the values of KMO are measured for each BIM risk and are usually ranging between 0 and 1, it has been suggested that 0.6 is the minimum value to consider the measure as adequate (Kaiser, 1970). On the other hand, the Bartlett test is used to examine the null hypothesis ($p > 0.05$) that suggests that a correlation matrix of the examined risks cannot represent an identity matrix (common themes cannot be found among the risks). While the BIM risks received "Sig" values lower than 0.05 under all three BIM advantages as in ***table-30***, the KMO values for the risks suggest that only the impact ratings under the cost reduction and collaboration improvement advantages are adequate for factor analysis since they are both higher than 0.6.

Table 30: KMO & Bartlett Test for BIM Risks

KMO and Bartlett's Test				
		Cost Reduction	**Time Reduction**	**Collaboration Improvement**
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		**.660**	.514	**.666**
Bartlett's Test of Sphericity	Approx. Chi-Square	312.299	374.071	325.135
	df	153	153	153
	Sig.	.000	.000	.000

8.2.2 Total Variance and Scree Plot:

This type of test is used to find the significance of the correlations of all risk components found in the factor analysis process and to reduce any insignificant ones. Punch (2005) claims that components with a total value below 1 under the "Initial Eigenvalues" must be omitted. As shown in ***tables 31 & 32***, there are 6 BIM risk components with significant correlations under the cost reduction advantage and 5 components under the collaboration improvement advantage.

Table 31: Total Variance for BIM Risk Components under Cost Reduction

Total Variance Explained						
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.457	35.870	35.870	6.457	35.870	35.870
2	2.119	11.773	47.643	2.119	11.773	47.643
3	1.714	9.522	57.165	1.714	9.522	57.165
4	1.450	8.056	65.221	1.450	8.056	65.221
5	1.219	6.773	71.994	1.219	6.773	71.994
6	1.061	5.893	77.887	1.0608	5.893326506	77.88693103
7	.816	4.534	82.421			
8	.610	3.390	85.811			
9	.584	3.245	89.056			
10	.499	2.772	91.828			
11	.434	2.411	94.239			
12	.245	1.362	95.601			
13	.233	1.294	96.895			
14	.202	1.120	98.015			
15	.143	.796	98.811			
16	.104	.577	99.388			
17	.064	.357	99.746			
18	.046	.254	100.000			
Extraction Method: Principal Component Analysis.						

Table 32: Total Variance for BIM Risk Components under Collaboration Improvement

Total Variance Explained						
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.208	34.488	34.488	6.208	34.488	34.488
2	2.849	15.828	50.316	2.849	15.828	50.316
3	1.679	9.327	59.643	1.679	9.327	59.643
4	1.309	7.272	66.915	1.309	7.272	66.915
5	1.214	6.744	73.659	1.214	6.744	73.659
6	.871	4.837	78.496			
7	.778	4.321	82.817			
8	.701	3.892	86.709			
9	.527	2.930	89.639			
10	.503	2.795	92.435			
11	.344	1.911	94.346			
12	.279	1.549	95.895			
13	.254	1.414	97.309			
14	.141	.785	98.094			
15	.136	.754	98.848			
16	.092	.513	99.361			
17	.071	.394	99.755			
18	.044	.245	100.000			
Extraction Method: Principal Component Analysis.						

The scree plots in ***figures 29 & 30*** give a graphical indication for the risk components with significant correlations, the number of suitable components is found at the point where the Eigenvalues drop lower than 1.

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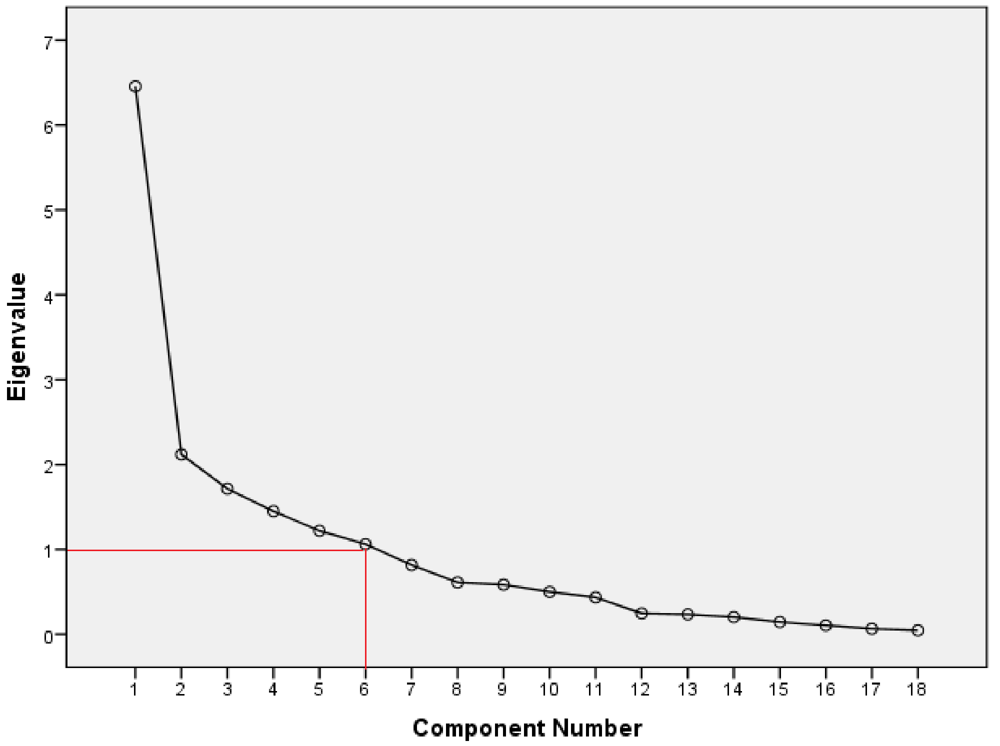


Figure 29: **Scree Plot for Total Variance of BIM Risk Components under Cost Reduction**

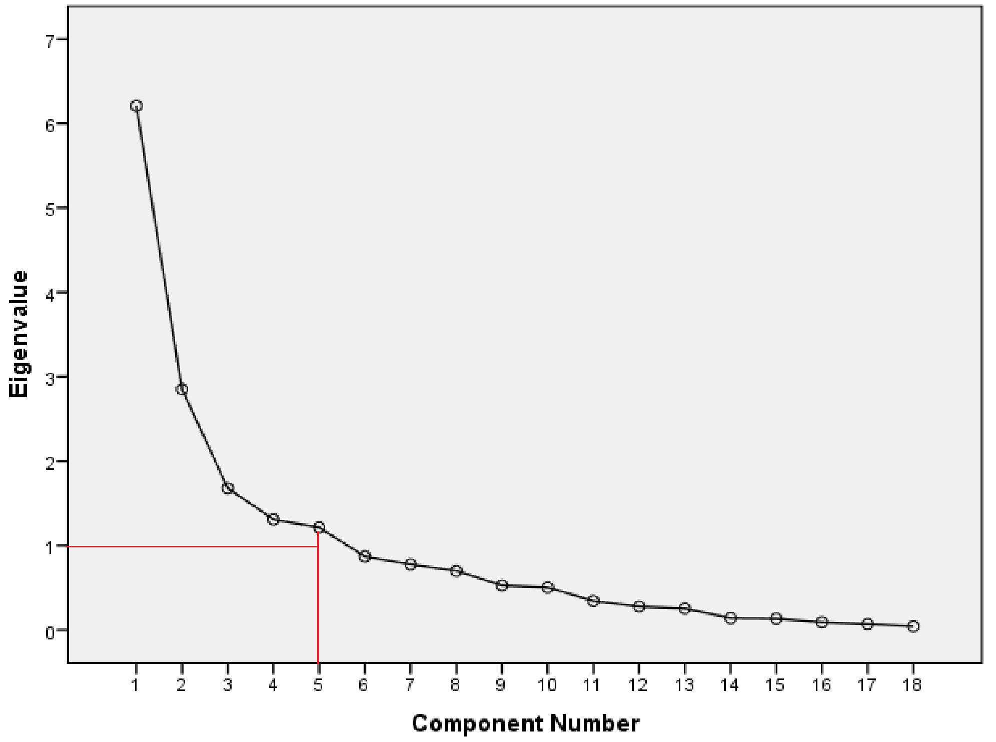


Figure 30: **Scree Plot for Total Variance of BIM Risk Components under Collaboration Improvement**

8.2.3 Rotated Component Matrix:

The purpose of performing this test is to find which BIM risks fall in each of the earlier mentioned BIM risk components under cost reduction and collaboration enhancement. Risks that have rotated component values higher than 0.05 (absolute values) under a certain risk component indicate that they belong to that specific component, when a risk has more than one value higher than 0.05 then either the higher one is selected or the one that puts the risk in a more reasonable component is selected.

BIM Risk Components under Cost Reduction:

First, the rotated component matrix is analyzed for BIM risks based on their impact on the cost reduction advantage, ***table 33*** shows how the 5th component has been deleted since it has only one risk "PR.12" trained/recruited BIM people leaving their company, this risk has been moved to the 4th component that has two risks also concerned with the BIM training and recruitment process. Furthermore, the risk "PR.9" unwillingness of team members to share information received two close values that are higher than 0.5 (0.554 and 0.557), the lower value (0.554) has been selected in order to move the risk to the 1st component which has similar team collaboration challenges.

Table 33: Rotated Component Matrix for BIM Risk Components under Cost Reduction

Rotated Component Matrix[a]						
	Component					
	1	2	3	4	5	6
PR.1	**.623**	.437	.150	.125	.254	.202
T.1	.249	.243	-.069	**.753**	.298	.318
PL.1	-.097	.001	.194	**.885**	-.061	-.023
PR.2	.173	.095	**.898**	-.037	-.076	.094
PR.3	.015	**.856**	.149	-.111	-.051	.255
PR.4	.447	**.686**	.010	.234	.222	-.089
PL.2	.101	**.557**	-.038	.235	.357	.387
PR.5	-.008	-.009	**.931**	.116	.221	.015
T.2	.390	**.498**	.364	.326	-.186	.025
PR.6	**.646**	.394	.092	.207	-.128	.299
PR.7	**.527**	.071	.349	.030	.516	.125
PR.8	.128	.308	.135	-.330	.328	**.618**
PR.9	**.554**	.286	**.557**	.175	-.019	.153
PR.10	**.825**	-.031	.056	-.070	.230	.071
PR.11	.248	.083	.100	.287	.017	**.840**
PR.12	.123	.027	.049	.075	**.859**	.131
PR.13	.448	.182	-.022	**.602**	.395	.023
PR.14	.162	**.524**	-.058	.324	.508	-.363

The resulting five latent groups from the ratings of BIM risks under cost reduction are shown in ***table 34***, it appears that component 1 is mainly concerned with team coordination issues while the third component is associated with the process of BIM training and recruitment, component 2 seems to have a combination of different BIM risks that have liability implications (legal, contractual, technological, upper management support and staff skills), the fourth component has three risks that make a different combination of liability challenges (BIM incompatibility, unawareness of BIM parametric concepts and undefined model copyrights), the sixth and final component combines the hardware/software costs of BIM with the time challenge of creating the initial BIM model.

Table 34: Resulting BIM Risk Components under Cost Reduction

Component 1		Component 2		Component 3		Component 4		Component 6	
PR.1	Project team's lack of experience in BIM	PR.3	Other project parties won't adapt BIM because of not knowing its benefits/preferring traditional method	PR.2	Costs of training and recruitment	T.1	Incompatibility of BIM programs and loss of data	PR.8	Cost of upgrading computers, technical support and software licenses
PR.6	Lack of internal team organization and definition of responsibility	PR.4	Absence of higher management support for BIM	PR.5	Time spent for BIM training & learning	PL.1	BIM model copyrights are not defined	PR.11	Time needed to start making the BIM model
PR.7	BIM's difficult implementation (It has to come in level by level)	PL.2	Lack of legal contracts specifically for BIM	PR.12	Recruited or trained BIM people leave their companies	PR.13	Unfamiliarity with BIM parametric concepts		
PR.10	Project concepts are produced using CAD	PR.14	Gap in staff skills in 4D (scheduling) and 5D (cost estimating)						
PR.9	Team members won't share information	T.2	Lack of electronic BIM standards (families, templates...etc)						

BIM Risk Components under Collaboration Improvement:

On the other hand, the rotated component matrix for BIM risks following their effect on the collaboration enhancement advantage is shown in ***table 35***, the risk "PR.10" execution of project concepts in CAD received two similar values above 0.5 (0.531 and 0.501), the smaller value has been selected in order to shift the risk from the 2nd component (most risks concerned with team collaboration) to the 5th component which had only one challenge "PR.11" time needed to create the initial BIM model, this has been done because of an assumed relationship between transferring a project from CAD to BIM and the additional time needed to start making the BIM model. Moreover, the risk "PR.12" recruited/trained BIM staff quitting their companies received 0.553 in the 1st component and 0.464 in the 3rd one, although 0.5 is the minimum value considered for correlation significance, it makes more sense to move this risk to the 3rd component which already has two challenges associated with the BIM training and recruitment process rather than the first component that has a blend of different risks.

Table 35: Rotated Component Matrix for BIM Risk Components under Collaboration Improvement

Rotated Component Matrix[a]					
	Component				
	1	2	3	4	5
PR.1	.017	**.797**	-.180	.166	-.049
T.1	**.683**	.288	.081	.132	.267
PL.1	.107	.059	-.120	**.801**	.102
PR.2	.276	-.083	**.796**	-.021	.145
PR.3	.397	**.766**	.030	-.073	-.189
PR.4	**.699**	.296	-.204	.311	.137
PL.2	**.717**	.068	-.148	.181	.490
PR.5	-.137	-.137	**.768**	.062	.209
T.2	**.669**	.113	.229	.314	.114
PR.6	.435	**.754**	-.083	-.037	.285
PR.7	.188	.381	.365	**.658**	.036
PR.8	.152	-.153	.222	**.640**	.557
PR.9	.267	**.836**	-.083	.102	.023
PR.10	.106	**.531**	.214	.094	**.501**
PR.11	.111	.014	.383	.201	**.816**
PR.12	**.553**	.100	**.464**	.329	-.405
PR.13	**.855**	.240	.055	-.196	.017
PR.14	**.667**	.205	.179	.089	-.205

The main findings from the five latent groups that resulted from the collaboration ratings are shown in ***table 36***, it appears that two components are similar to the ones from the cost reduction ratings where the second component primarily consists of team collaboration risks and the third component is concerned with the BIM training and recruitment process. Another resemblance to the cost reduction findings is that the first component in collaboration improvement has a similar mixture of BIM liability challenges as the second component in cost reduction (technological, legal, higher management support and staff skills). Additionally, the fourth component combined a legal BIM risk, an implementation challenge and a cost barrier together while the fifth and final component is concerned with project conversion from CAD to BIM and the time required for building the initial BIM model.

Table 36: Resulting BIM Risk Components under Collaboration Improvement

Component 1		Component 2		Component 3		Component 4		Component 5	
T.1	Incompatibility of BIM programs and loss of data	PR.1	Project team's lack of experience in BIM	PR.2	Costs of training and recruitment	PL.1	BIM model copyrights are not defined	PR.11	Time needed to start making the BIM model
PR.4	Absence of higher management support for BIM	PR.3	Other project parties won't adapt BIM because of not knowing its benefits/preferring traditional method	PR.5	Time spent for BIM training/learning	PR.7	BIM's difficult implementation (It has to come in level by level)	PR.10	Project concepts are produced using CAD
PL.2	Lack of legal contracts specifically for BIM	PR.6	Lack of internal team organization and definition of responsibility of members' model input	PR.12	Recruited or trained BIM people leave their companies	PR.8	Cost of upgrading computers, technical support and software licenses		
T.2	Lack of electronic BIM standards	PR.9	Team members won't share information						
PR.13	Unfamiliarity with BIM parametric concepts (parametric families)								
PR.14	Gap in staff skills in 4D (scheduling) and 5D (cost estimating)								

When looking at the common findings of the rotated component matrices of BIM risks under both the cost reduction and collaboration improvement advantages, it can be emphasized that one component is concerned with team collaboration, another is associated with BIM's training and recruitment, the third has a combination of liability risks (legal, contractual, technical, organizational, and staff expertise) while the two remaining components do not seem to have any shared themes.

8.2.4 Reliability Test of Components:

The five BIM risk components that resulted from the factor analysis process under cost reduction and collaboration enhancement are tested for validity by finding the values of Cronbach's Alpha for each of the components. As shown in ***table 37***, the first and second components under both advantages (component of team collaboration and component of legal, technical, contractual, upper-management and staff skills risks) as well as the fourth component under cost reduction (component with software and legal risks) are all considered reliable (Cronbach's Alpha higher than 0.7). On the other hand, the BIM training and recruitment component under both advantages along with the fourth and fifth components under collaboration improvement all received questionable reliabilities (Cronbach's Alpha between 0.6 and 0.7). Finally, the sixth component under cost reduction (BIM hardware/software costs and time needed to make the initial BIM model) received a poor reliability (Cronbach's Alpha less than 0.6).

Table 37: Reliability Test for BIM Risk Components under Cost Reduction and Collaboration Improvement Advantages

BIM's Cost Reduction

Component	**Cronbach's Alpha**	**N of Items**
Component 1	**0.825**	5
Component 2	**0.776**	5
Component 3	0.628	3
Component 4	**0.791**	3
Component 6	0.562	2

BIM's Collaboration Improvement

Component	**Cronbach's Alpha**	**N of Items**
Component 1	**0.862**	6
Component 2	**0.875**	4
Component 3	0.614	3
Component 4	0.682	3
Component 5	0.623	2

8.3 Chapter Conclusion:

The BIM risk factor analysis chapter began by conducting a KMO & Bartlett test in order to determine the suitability of the sample for factor analysis, the resulting adequate BIM risk ratings were only under the cost reduction and collaboration improvement advantages, then total variance tests and scree plots highlighted the number of risk components with significant correlations, after that a rotated component matrix for BIM risks resulted in five components under each BIM advantage, however the reliability of the risk components found that only three were reliable, the first component is associated with team collaboration risks, the second is a combination of liability risks including contractual, legal, technological, higher management and team skills challenges and the third and final component is also concerned with liability through legal and software risks.

CHAPTER 9: DISCUSSION, CONCLUSIONS & RECOMMENDATIONS:

9.1 Chapter Introduction:

The final chapter of this paper discusses the main findings from the research analysis; it attempts to find a relationship between the findings from the literature, the questionnaire and the interview. This chapter describes the most influential BIM risks based on the survey results and compares them to their context in the interview and the literature. Furthermore, this chapter examines the impact of BIM challenges on its advantages and its connection with the demographic backgrounds of the respondents to either prove or reject the suggested research hypothesis in ***Chapter 4***, then it analyzes the BIM risk components found in the factor analysis in ***Chapter 8***, after that it uses the suggestions in the interview to recommend a number of strategies for managing BIM risks.. Finally, it explains the implications of this research on the industry, clarifies its main limitations and proposes certain areas for future investigation.

9.2 Discussion of the Analysis Findings:

9.2.1 Impact of BIM Risks on its Advantages:

This section summarizes the main outcomes from the survey concerning the importance of BIM risks, it relates those outcomes to the findings from the literature and the interview, after that it discusses the impact of those risks on BIM advantages found in the questionnaire as compared to the impact suggested by other researchers. It also analyzes the main differences and similarities between the BIM risk ratings of respondents based on their professional attributes.

One of the main highlights of the BIM risks ranking under its advantages in ***figure-31*** is that the top risks for all three advantages were related to project team collaboration and experience including "PR.1" project team's lack of BIM experience, "PR.6" lack of internal team organization and liability definition and "PR.9" reluctance of team members to share information, it also appears that most of the categories under the demographic groups of the respondents agreed internally on the impact of these experience and collaboration challenges. These findings mean that respondents perceive the high importance of the collaboration process in BIM and it being the focal point of the BIM application as a whole, they also understand how its poor management is the main contributor to additional time and cost in projects. This finding comes in conjunction with several studies in the literature including the survey by Eadie et al.

(2013) that ranked the top BIM challenge as lack of experience. Additionally, the senior products manager in the interview that was conducted agreed by stating that the main team issue that he has faced in his organization is communication, even though he states that the collaboration challenge is not only in BIM projects, he argues that the lack of team experience in the new 3D environment of BIM does create additional problems.

In addition, the time reduction advantage received a direct time challenge as the top risk which is "PR.5" Time for BIM learning/training, however the required time to begin making the BIM model which has been indicated by Bryde, Broquetas and Volm (2013) and Gray et al. (2013) received the third lowest impact on the time reduction advantage. Another observation from the severity indices of BIM risks in the questionnaire is that the two main legal BIM challenges "PL.1" undefined BIM model ownership and "PL.2" lack of legal contracts specifically for BIM were among the lowest rated risks for all three advantages. The highest rating among all advantages was the impact of team members' reluctance to share information on BIM's collaboration enhancement (83% severity) while the lowest was for the impact of BIM hardware/software costs also on collaboration improvement (53% severity).

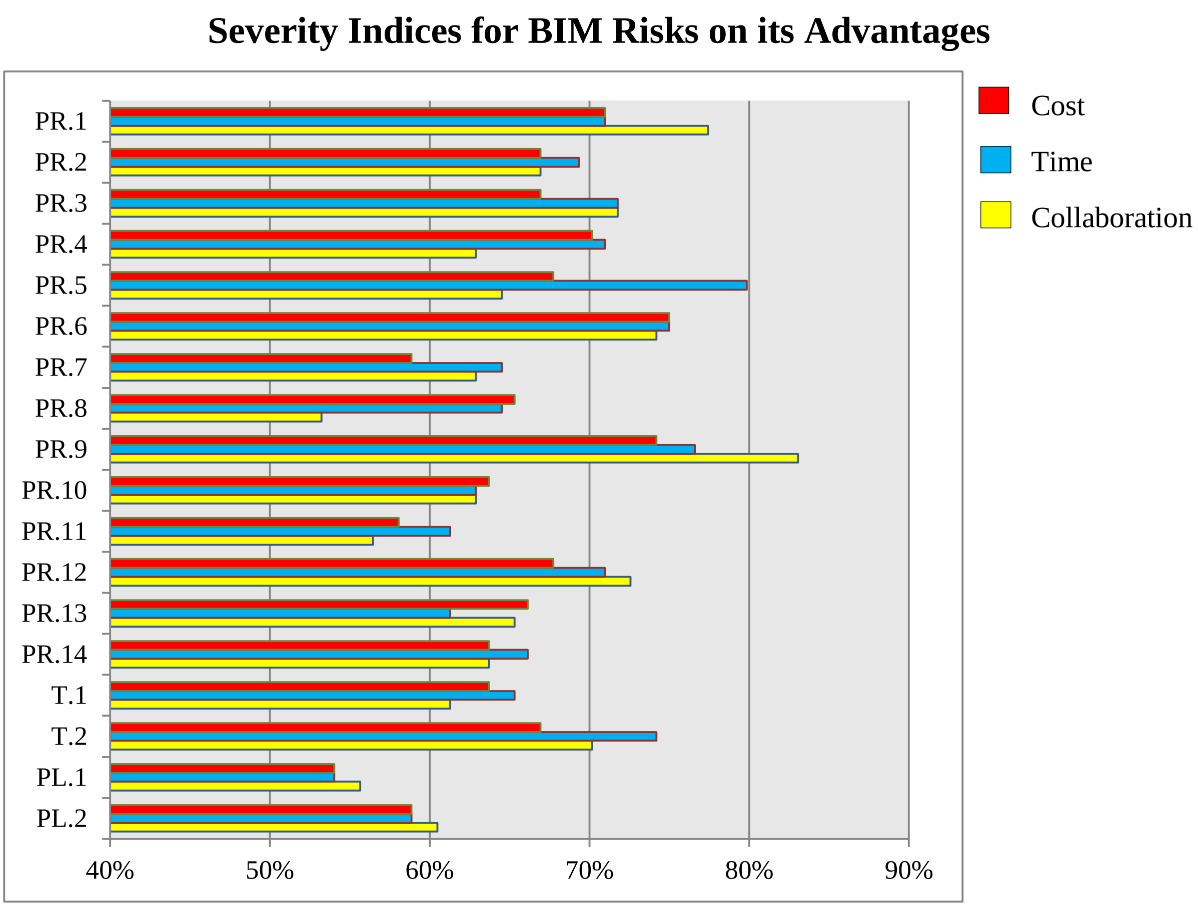


Figure 31: **Severity Indices for BIM Risks on its Advantages**

As for the ratings of respondents in the context of their professional profiles, contractors had overall lower impact ratings on all three BIM advantages as compared with consultants; this supports the finding by Jones (2015) which claims that BIM offers more benefits to contractors than consultants. Moreover, a study by Chien, Wu and Huang (2014) found that consultants generally see more significance for the lack of BIM standards on successful BIM adoption, this finding has been backed by the questionnaire since respondents from consulting companies had a higher impact rating for the lack of electronic BIM standards on all three BIM advantages, additionally the senior products manager in the interview tool used in this research stressed on the absence of a BIM standard specifically for the UAE. However, the survey results did not agree on another suggestion in the study by Chien, Wu and Huang (2014) that contractors have a higher perception for the issue of data interoperability in BIM since respondents from consulting firms rated the effect of BIM incompatibility risk higher for two of the three BIM advantages.

Furthermore, contractors agreed with consultants on the impact of poor information sharing although they seem to have a higher perception of the effect that BIM training and recruitment have on all of its three advantages. Manning and Messner (2008) mentioned the example of a hospital facility where the contractor was unwilling to adopt BIM and was insisting on the traditional CAD method, this case study has been supported by the questionnaire through the consultants' higher ratings of the BIM risk of other project parties not incorporating BIM because of their unawareness of its benefits or preferring the traditional method, on this matter the senior products manager in the interview in this paper focused on the importance of partnering procurements among all project stakeholders (owner to subcontractor) in order to fully realize the benefits of BIM.

Jones (2015) suggested that contractors generally have a more positive outlook regarding BIM's cost reduction which has been supported by the consultants' higher ratings of the BIM risk "hardware/software costs of BIM" as well as their slightly higher overall ratings for the cost reduction advantage. In contrast, the suggestion by Jones (2015) that consultants are more optimistic about the time savings of BIM was not proved by the questionnaire as the overall ratings of consultants for the impact of BIM risks on time reduction were slightly higher than the ratings of contractors.

Similarly, respondents from both large and small organizations agreed on the impact of team issues on BIM's advantages. The effect of training and recruitment costs in addition to the software and hardware expenses on BIM's cost reduction was rated higher by respondents from small companies which comes in line with the suggestions by Newton and Chileshe (2012) and Zahrizan et al. (2013) that small firms suffer when adopting BIM due to its direct investment costs, this has also been backed by the interview through the idea that small firms have minor profit margins at the start of the BIM implementation process.

Both large and small organization groups settled on the impact of BIM recruitment and training on the time advantage and despite the fact that people in large companies rated the impact of training and recruitment higher on collaboration, it seems that respondents in smaller firms had slightly higher ratings for all the risks associated with collaboration in general, this does not support the notion in the interview that larger organizations face additional challenges in coordination during BIM adoption because of their size as well as having multiple international offices. Another outcome is that respondents from large organizations perceive higher management support more while those in smaller firms are more worried about technology challenges, this can be justified by stating that larger firms require more upper management endorsements and strategies because it is more difficult to implement BIM in a larger environment, moreover smaller companies are affected by software issues due to their limited capabilities.

Following the first two demographic groups, both architects and non-architects (engineers, draftsmen and BIM/design managers) agreed on the effect of internal team challenges on BIM advantages. The most obvious finding is that architects are more concerned with higher management support as well as other project parties not implementing BIM while non-architects seem to have a generally higher perception of the impact of BIM's training and recruitment on all of its three advantages. The finding for non-architects comes in conjunction with the suggestion by Jones (2015) that engineers have a larger perception than architects when it comes to the impact of missing skills in advanced technologies such as BIM. Architects rated the impact of BIM's incompatibility issue on two of the three BIM advantages higher than non-architects which support the finding by Jones (2015) that engineers perceive data exchange challenges less importantly than architects. Additionally, McGraw-Hill (2010b) found in a survey that architects have more positive views on the return on investment of BIM as compared to engineers; this result was confirmed by the questionnaire in this paper as the architects' overall ratings for the impact of BIM risks on the cost reduction advantage were lower than those by the non-architects group.

Both experienced and less experienced respondents agreed on the impact of team challenges on the time and collaboration advantages. Although both groups met on the effect of BIM training and recruitment on the time advantage, less experienced respondents seem to worry about its impact on cost and collaboration more than experienced ones. Moreover, experienced professionals are more concerned with project transfer from CAD to BIM, this is assumed to be true because of their expected higher expertise in CAD and the resulting higher perception of its challenges as compared to less experienced respondents, those with higher experience also had higher rankings for upper management support and lack of specific BIM legal contracts, the latter challenge was mentioned by the senior products manager in the interview in this research by emphasizing the importance of developing new contracts for BIM that incorporate the new contractual relationships and ensure that all stakeholders are benefiting from the BIM application.

All respondents who have more than 5 years of BIM experience were not architects; this came in agreement with the result of the survey by Chien, Wu, and Huang (2014). Moreover, the three categories under this group (no BIM experience, less than 5 years and more than 5 years) agreed on the impact of project team issues on all of BIM's advantages. Similarly, all three categories met on the impact of BIM recruitment and training on the time advantage, those with no/small BIM experience agree on the effect of this process on cost reduction while those with high BIM experience see a higher impact for training/recruitment on collaboration. Two outcomes that were consistent with the general experience findings were that respondents with higher BIM experience are more worried about upper management support as well as project concepts being produced in CAD. Underwood et al. (2015) suggested that the perception of BIM technology risks increases with more BIM experience, this suggestion was denied by the decreasing ratings for both the incompatibility of BIM programs and the lack of electronic BIM standards with more BIM expertise. On the other hand, McGraw-Hill (2010b) discovered in a study that professionals with high BIM experience perceive the profitability of BIM more than those with less experience, this finding was not confirmed in the questionnaire as the ratings of respondents from all BIM experience groups for the first cost challenge (training/recruitment costs of BIM) were approximately similar, in addition to that the ratings of respondents with no BIM experience for the second cost challenge (BIM hardware/software costs) were considerably lower than those with small/large BIM experience.

9.2.2 **Hypothesis Testing** (BIM Risk Ratings based on Demographic Groups)**:**

This section discusses the results of the variance tests in ***chapter 7*** including the independent t-test and the one-way ANOVA test, this is done to either prove to reject the research hypothesis which suggests that there is a significant difference in respondent ratings of the impact of BIM challenges on its advantages based on their professional backgrounds.

The first finding is that there is a significant difference between the ratings of consultants and contractors of the impact of “PR.2” BIM training and recruitment costs on both the time reduction and collaboration enhancement advantages, although this risk is a direct cost challenge and cannot have an impact on time savings or collaboration improvement, it has been suggested that contractors rated this risk significantly higher than consultants because of their larger perception of the impact of BIM’s training and recruitment process as a whole on BIM’s advantages, this is because contractors’ top rated risks for all three advantages are related to the process of recruitment and training.

The second finding is that there is a significant difference between the ratings of experienced and less experienced professionals of the impact of “PR.10” execution of project concepts in CAD on BIM’s cost reduction advantage. It appears that more experienced respondents had a higher rating for this BIM challenge, this has been explained by suggesting that experienced professionals have more knowledge and expertise with the traditional CAD method as compared to less experienced ones, meaning that they have a better understanding of the implications of transferring the project from CAD to BIM.

9.2.3 Factor Analysis:

The process of factor reduction for BIM risks found from a KMO & Bartlett test that even though risk ratings under all three BIM advantages can be used for factor analysis, only the ratings under the cost reduction and collaboration enhancement advantages would be considered adequate. As for the cost reduction advantage, the total variance test emphasized six BIM risk components with one of the components having only one risk "PR.12" trained/recruited BIM people leaving their firms; this risk has been moved to another component that includes training/recruitment challenges. Out of the five components, one is associated with team collaboration issues, the second is a combination of liability risks including technological, legal, contractual, higher management and staff skills challenges, the third is concerned with BIM training and recruitment, the fourth involves legal and software risks while the fifth includes the time required to make the initial BIM model as well as the hardware/software costs of BIM.

On the other hand, the total variance test for BIM risks under collaboration improvement highlighted five significant components where three of those five were similar to another three under the cost reduction advantage, those three are (team coordination component, BIM training and recruitment component and the legal, contractual, technical, upper management and staff expertise component), the fourth component shared legal, BIM adoption and cost risks while the fifth one included project transfer from CAD to BIM and the time needed to create the BIM model.

The reliability test of the above mentioned risk components found that only three of them are valid, those three are: **1- Team Collaboration Component**, **2- Liability Component (1)** **3- Liability Component (2)**. The first liability component contains the legal, technological, contractual, staff capabilities and higher management support risks mentioned earlier which were all assumed to have liability implications. The second liability component contains legal as well as technology challenges.

9.3 Strategies for Mitigating BIM Risks (from Interview):

This section presents a set of strategies and solutions to manage the risks of BIM which were suggested in the interview explained earlier.

The senior products manager interviewed focused on the BIM issue highlighted by Volk, Stengel, and Schultmann (2014) about the discrepancy in BIM adoption levels between developed and less developed countries due to investment needs and lack of practical adoption plans, he argued that external drivers are considered as the first contributers to any major industry process change incuding the engagements of external parties such as public and government entities and the creation of global comittees that drive the implementation of BIM. Additionally, he agreed that international initiatives to drive BIM adoption can have an impact and he gives the example of the investments done by certain Chinese companies in Africa where the local industries had to incorporate BIM through aggressive design and construction programs, he claims that this example can be adapted to other parts of the world. He argues that not all approaches to drive BIM have been led by governments and he gives the example of Qatar where government entities are involved in the supply chain which indicates more of a bottom-up approach.

Furthermore, the interveiwee suggests that having fixed milestones in the BIM implementation process can help achieve more BIM uses for the industry, he also states that the UK government and other parties involved in the BIM mandate are starting to provide more insurances and securities for companies that implement BIM and that they are moving in the direction of digital tools and contents rather than using paper tools. The engagements between governing authorities and main BIM dealers is mentioned with the example of the involvement of the NBS (National Building Specification in UK) with key vendors such as Autodesk and Trimble to create better digital tools for the whole industry. The interviewee argues that developing countries must reach a basic level of BIM maturity by producing fully coordinated designs in order to bridge the gap with advanced countries. As for BIM adoption in small firms, the interviewee suggests that with the right kind of resources as well as government funding, small organizations can overcome those challenges through a gradual process that deploys projects with reasonable sizes, this has also been backed by Bin Zakaria et al. (2013) through giving the example of the BCA government in Singapore which created a dedicated fund for BIM's hardware/software costs as well as the training expenses.

On the contractual level, the interviewee suggests that contracts must be adjusted and altered to suit the collaborative nature of BIM and that means that no party should lose out as a result of using BIM. He also states that public-private-partnerships can help a lot in the adoption of BIM and he gives the example of certain projects in Asia where governments collaborated with private construction companies. Finally, he agrees that partnering procurements can benefit the implementation of BIM and that it must be across the whole range of stakeholders from the client to the subcontractors.

When it comes to the company level, the interviewee agreed with Eadie et al. (2013) that BIM should not be treated as a technology and that its adoption affects all processes in the company. He argues that top level endorsements are mandatory for successful BIM adoption, this means that the higher management has to be behind the process and has to mandate it, there should also be a high-level strategy agreed on by the senior leadership team to be able to control all aspects of the process, then there must be a full program suggesting how BIM is going to be implemented. The interviewee shared some of the strategies implemented by his company to improve BIM such as having a strong culture of personal improvement which is reviewed twice a year, encouraging BIM as a goal for everyone in the organization by educating each person about the impact of BIM on their role in the company, he mentioned the example of teaching project managers how to deal with clients who lack knowledge in BIM and he also stated that the company is conducting a training course to help all employees understand the position of BIM in the company.

Finally, the interviewee claims that design teams have to focus only on resolving the major issues and clashes in a BIM model rather than wasting time and energy on very minor conflicts, he also states that sharing the new information and skills learned in BIM between project teams is essential for the process to work.

9.4 Research Implications:

This paper has presented a number of findings that can have an impact on the BIM research field. First, additional surveys can be used to verify that the top rated BIM challenges are related to team experience, internal organization and information sharing. Second, some of the findings that did not align with the literature can be used for further testing; this includes the difference in perception of BIM's time reduction advantage and the BIM interoperability issue between consultants and contractors, the difference in rating collaboration challenges between respondents in small and large organizations and finally the difference in views of the BIM cost reduction advantage and the BIM technology challenges based on BIM experience levels. Third, specific survey findings that were neither proved nor rejected in the literature such as the contractors' higher perception of the process of BIM training and recruitment, the larger perception of upper management support by architects, experienced professionals as well as those working in large organizations, and finally the experienced professionals' higher perception of the lack of legal BIM contracts and producing project concepts in CAD.

9.5 Limitations of the Study:

The major drawbacks of this research paper include the lack of local studies on BIM and its adoption in the UAE, the small sample size due to the somewhat recent introduction of BIM to the UAE construction industry as well as the lack of assistance and cooperation in filling the questionnaire by the majority of the design and engineering consultancies visited/contacted, other limitations that might have affected the outcomes of the questionnaire include the lack of comprehensive understanding of the BIM application, its main challenges and the way they affect its advantages for some of the survey respondents and finally the need to reduce the number of BIM risks from 32 to 18 and the number of BIM advantages from 9 to 3 after receiving complaints about the lengthiness of the questionnaire.

9.6 Areas for Future Research:

From the papers and journals examined in the literature review, it appears that there are a reasonable number of them that are addressing the topic of BIM challenges and advantages separately; however it seems that studies examining the relationship between the challenges and advantages of BIM are still lacking. Furthermore, there is little research on the relationship between the demographic characteristics of industry professionals including type and size of organization, position and general and BIM experience and their perceptions of the effect of BIM risks on its main advantages.

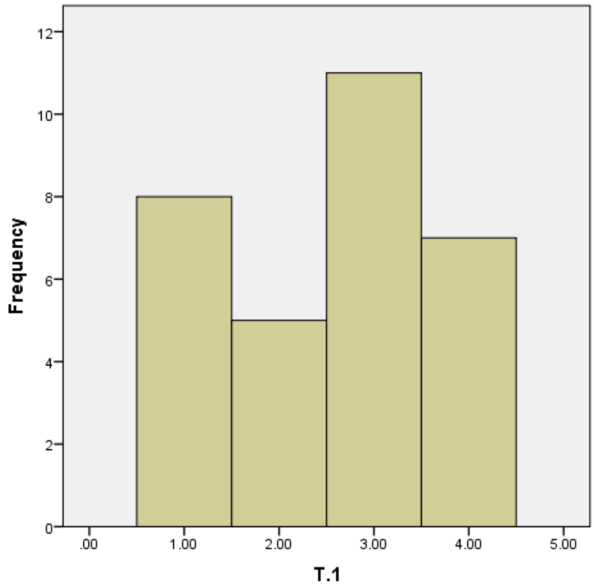
9.7 Chapter Conclusion:

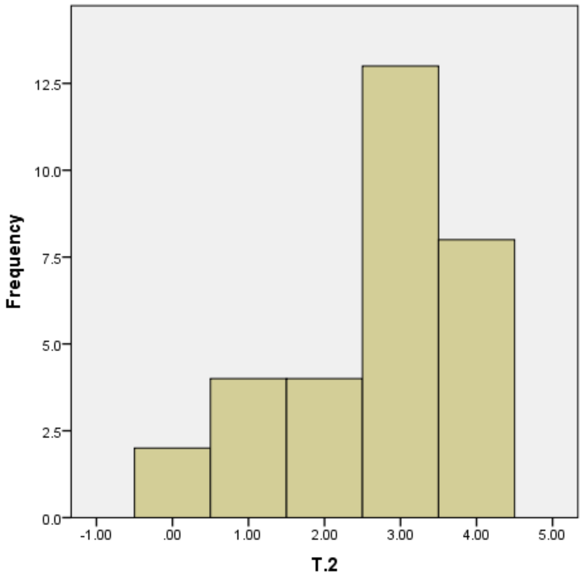
The ninth and final chapter of this paper started by discussing the key findings across the research analysis process, the main discussion attempted to link the outcomes of the questionnaire, the findings from the literature and the statements in the interview. Moreover, this chapter summarized the main results of the variance tests in ***Chapter 7*** to decide on the main research hypothesis that suggests a significant difference in respondents ratings of the impact of BIM challenges on its advantages based on their professional backgrounds, after that the main BIM risk components found in the factor analysis process were mentioned, a number of strategies for managing BIM challenges suggested in the interview were proposed, then the implications of this paper were stated, its main limitations and suggestions for future research.

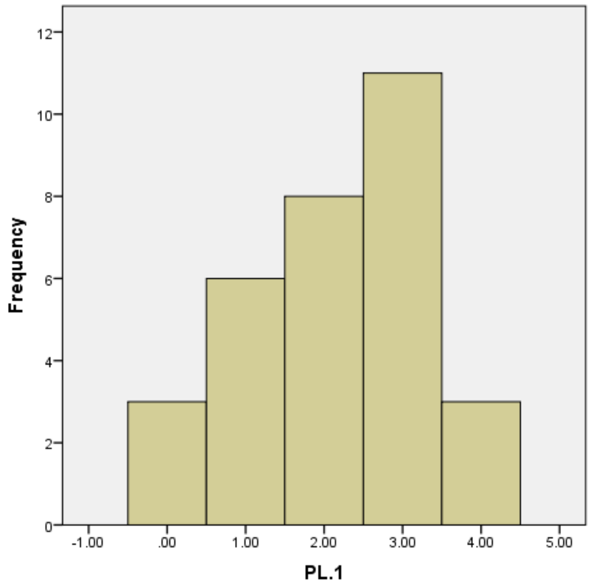
Appendices:

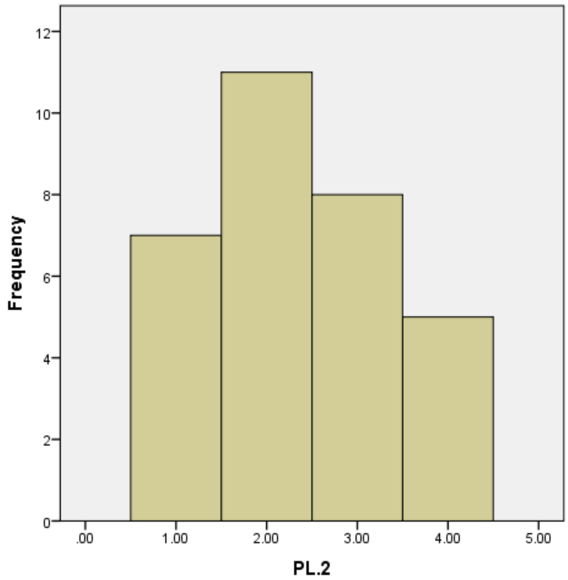
Appendix A: ***Frequency Distributions of the Impact of BIM Risks on its Advantages***

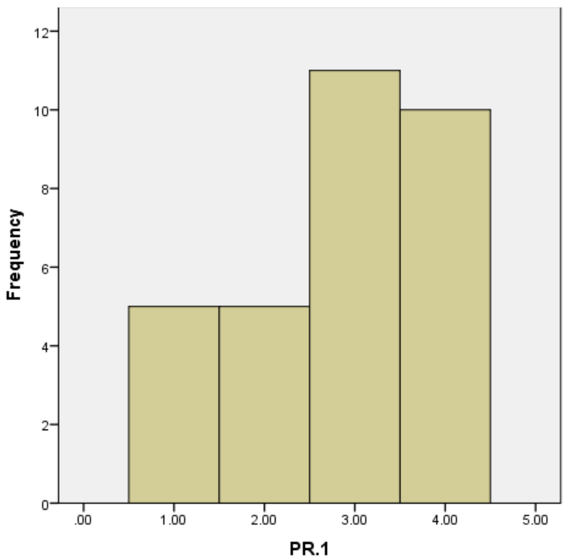
Cost Reduction

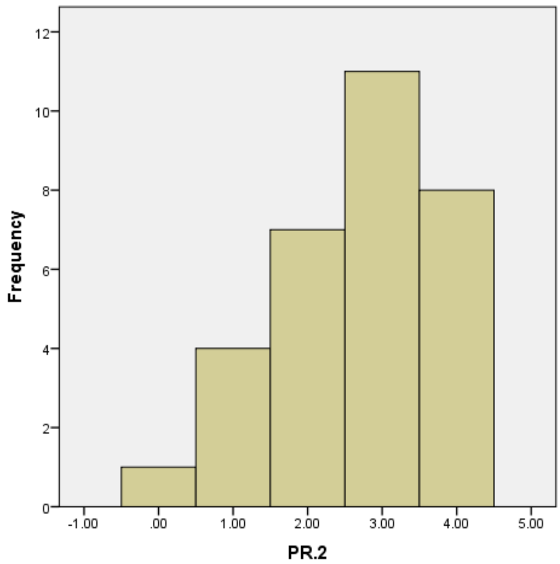


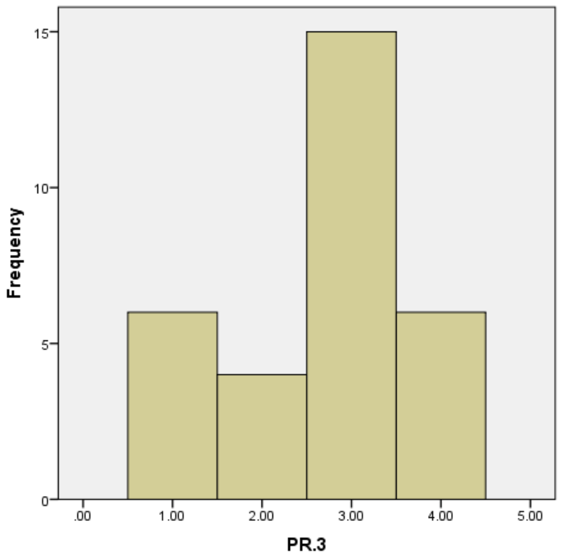








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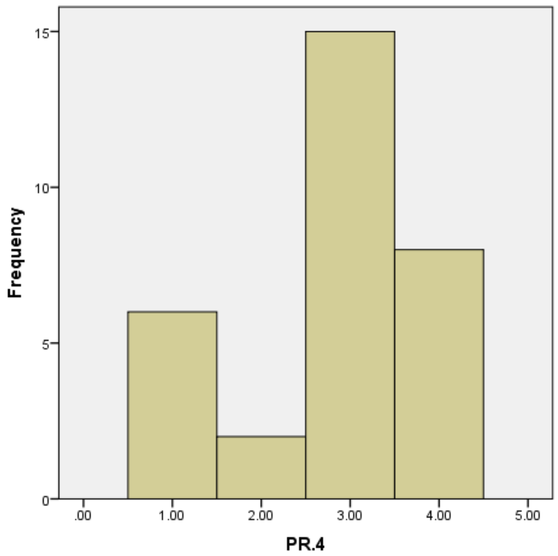
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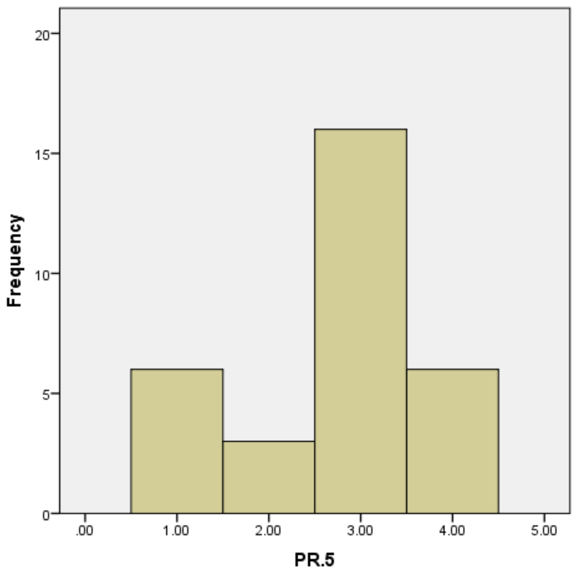
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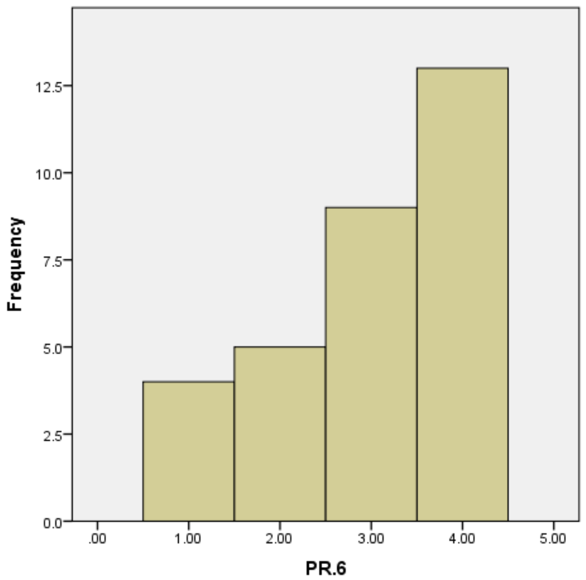
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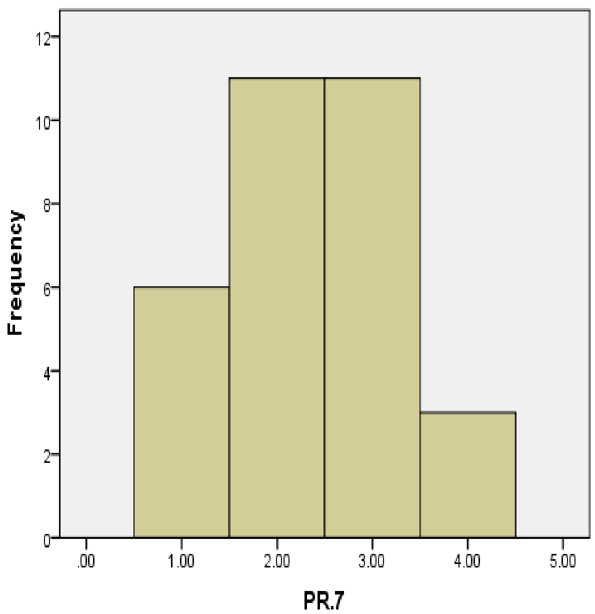
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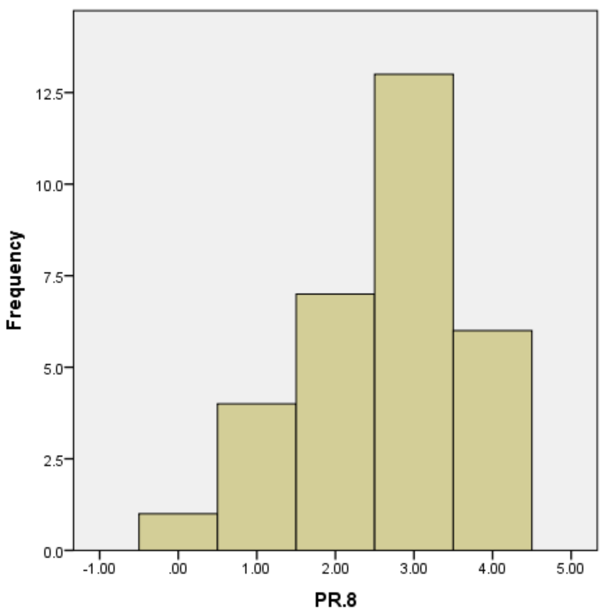
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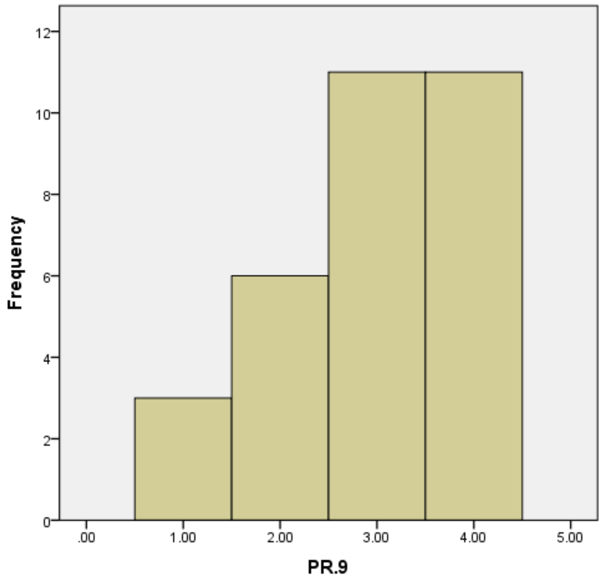
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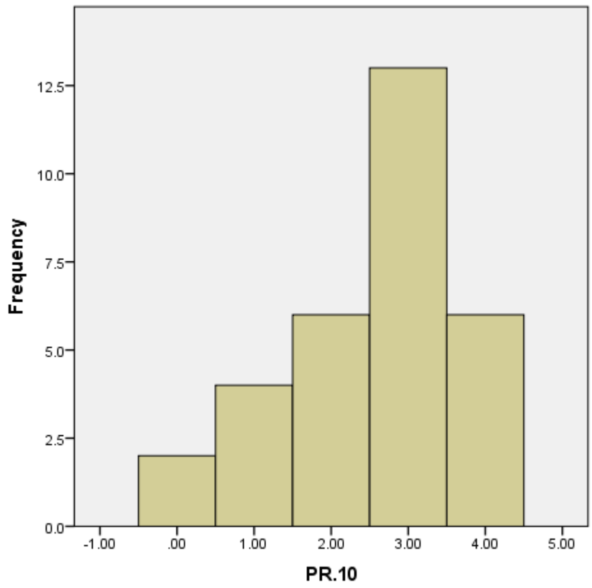
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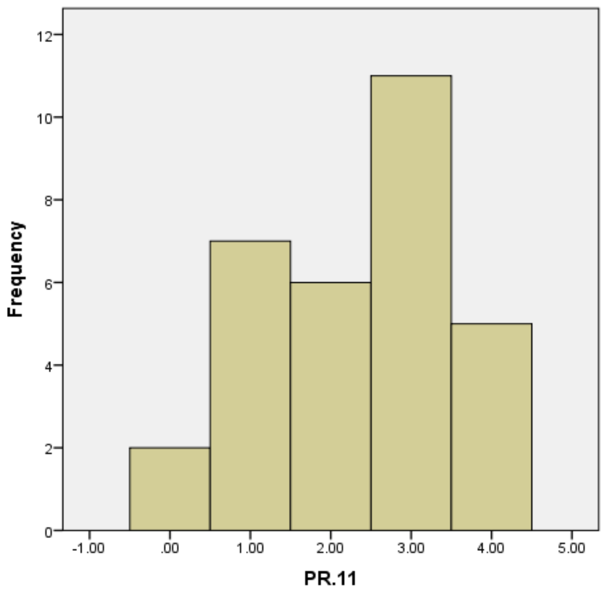
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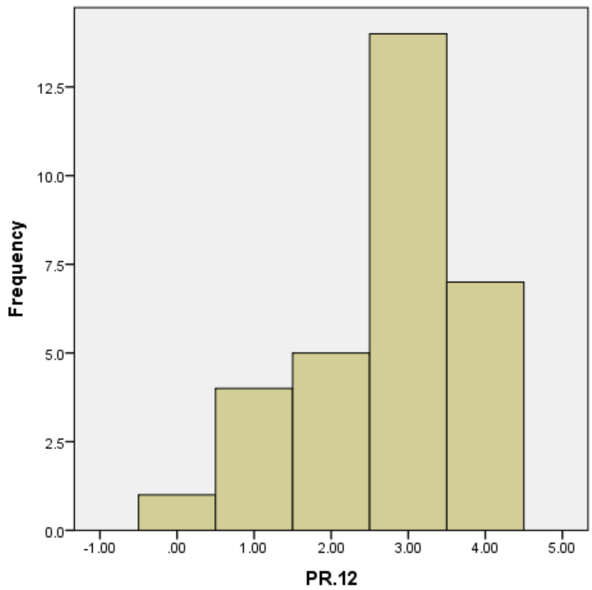
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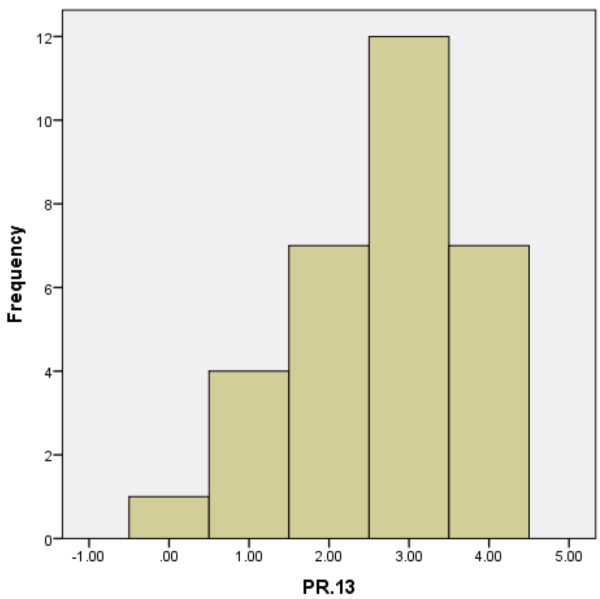
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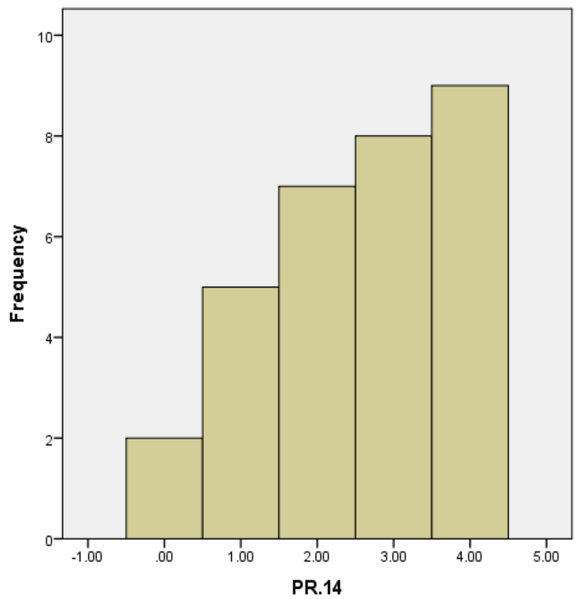
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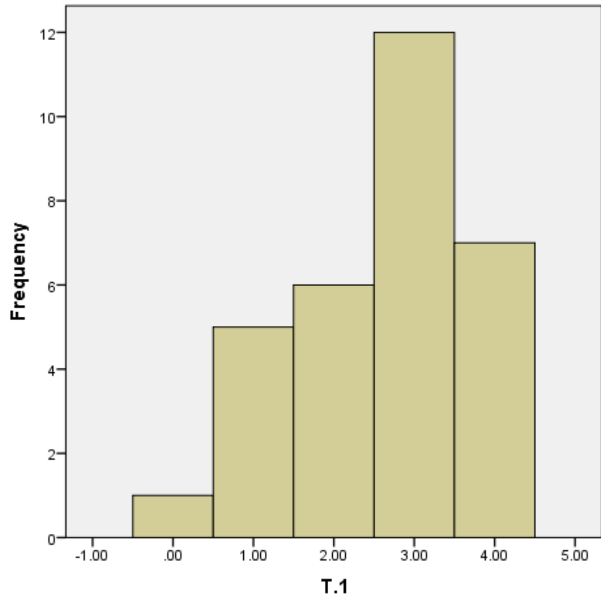

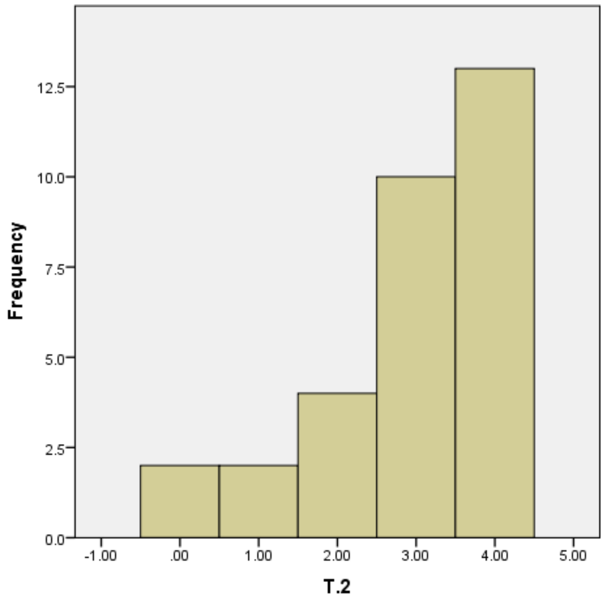

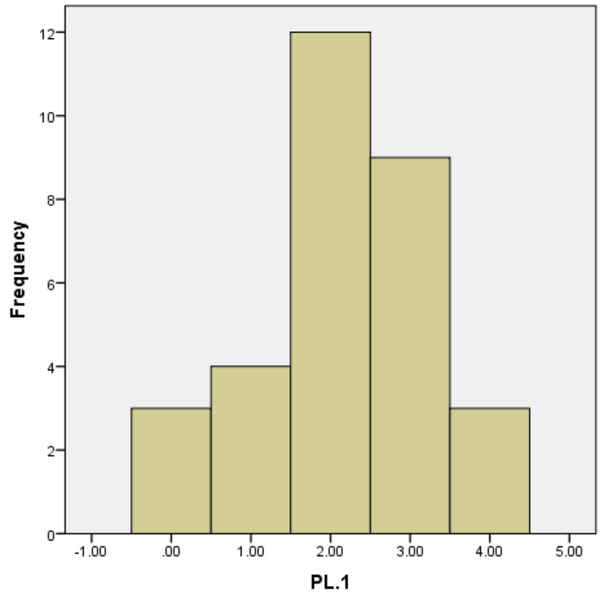

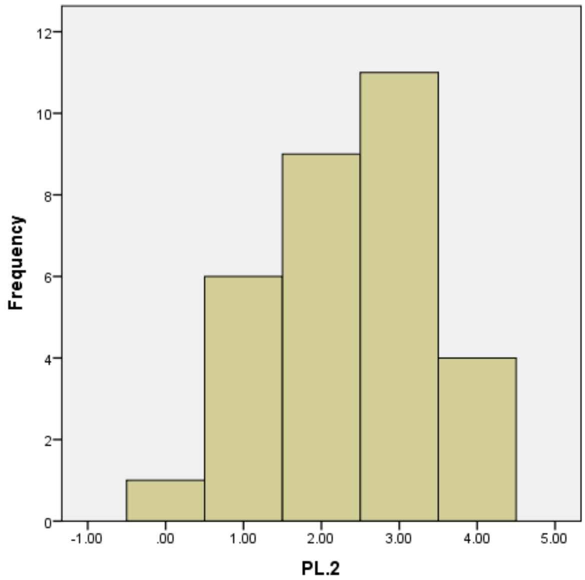

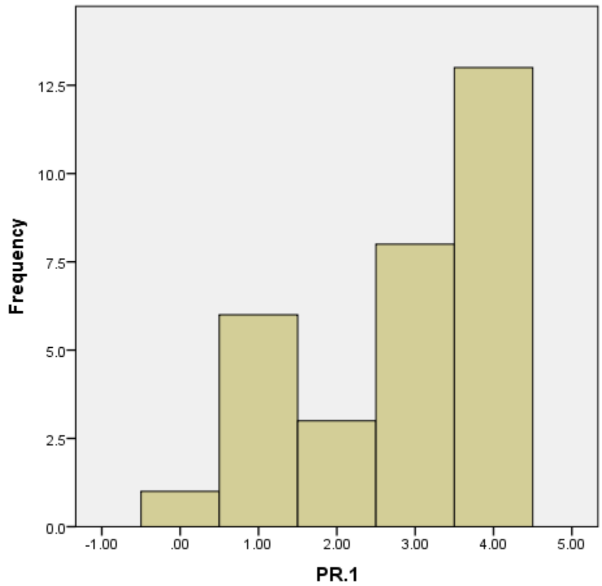

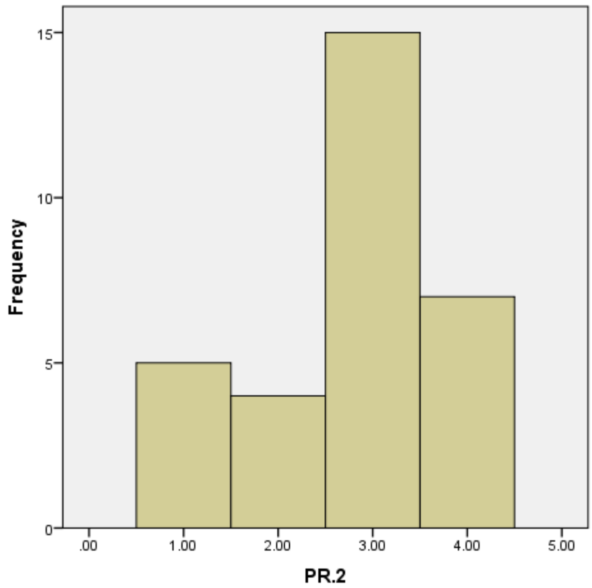

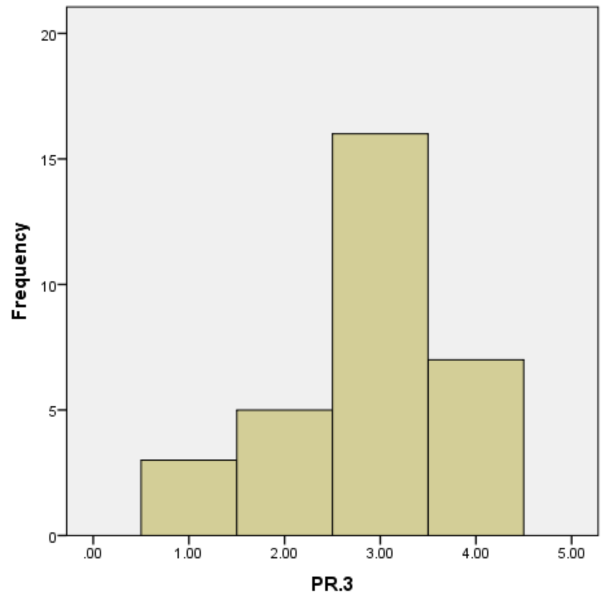
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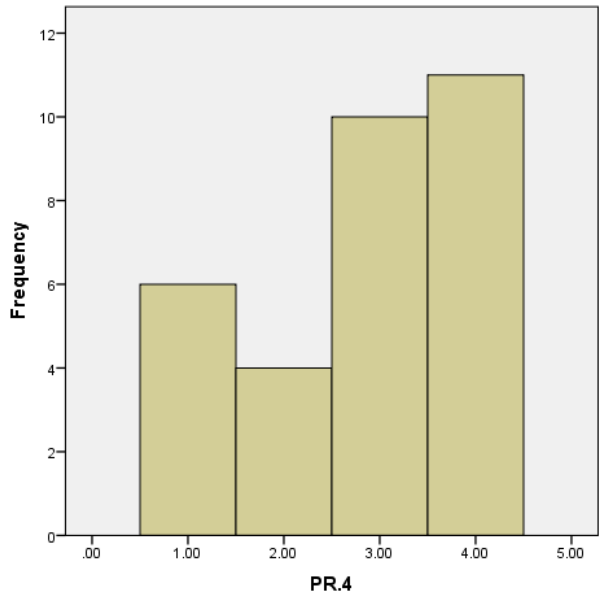
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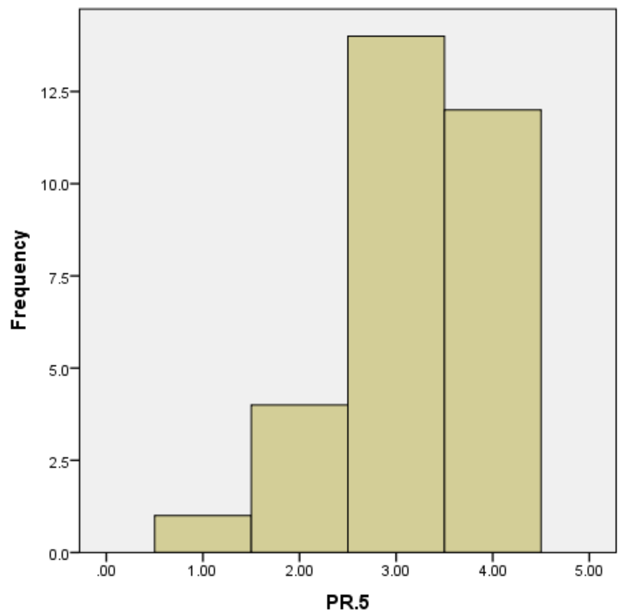
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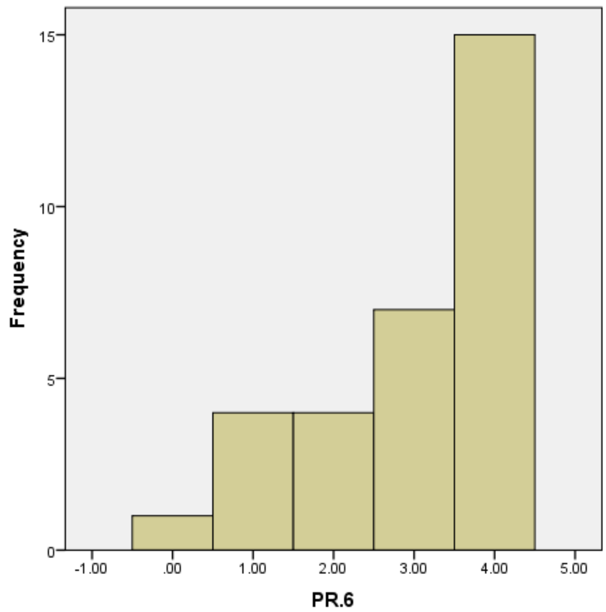
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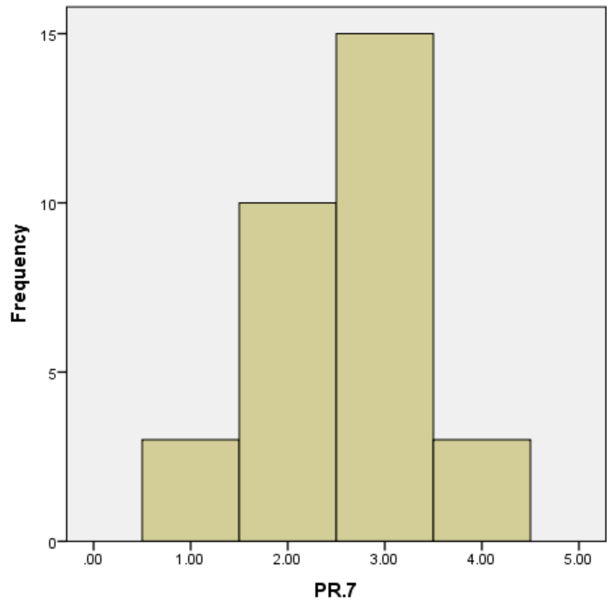
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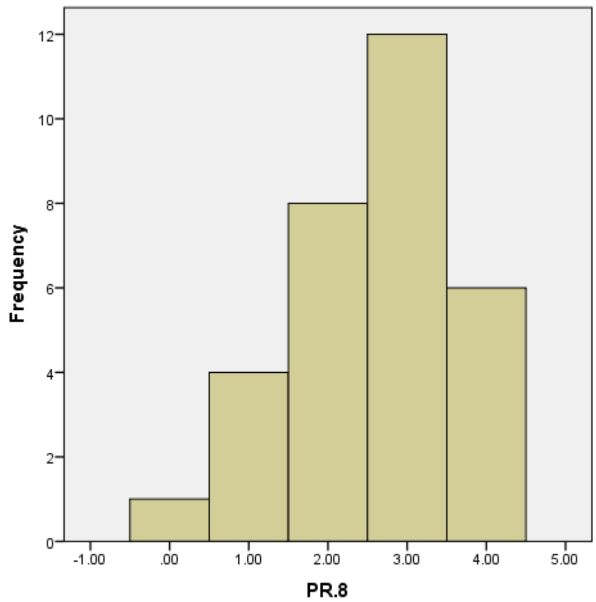
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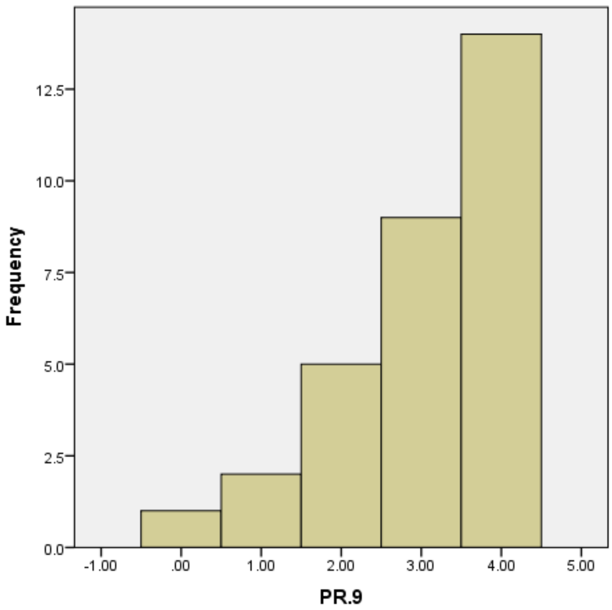
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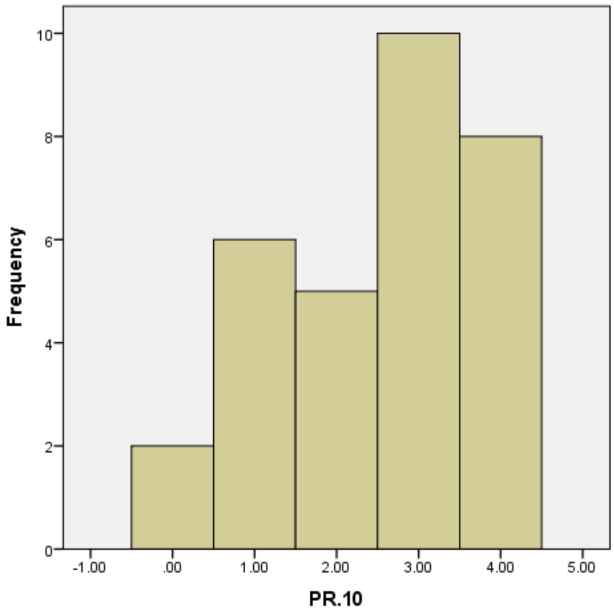
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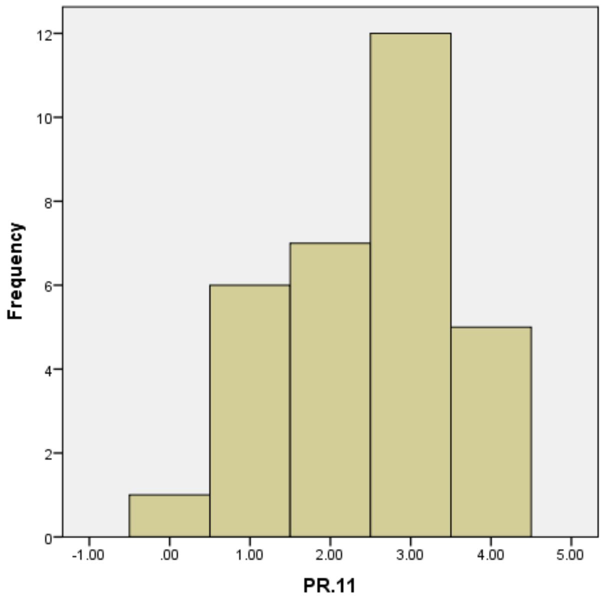
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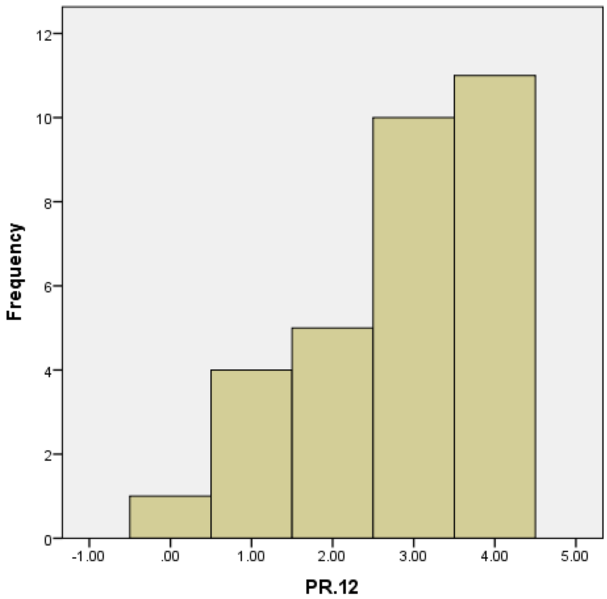
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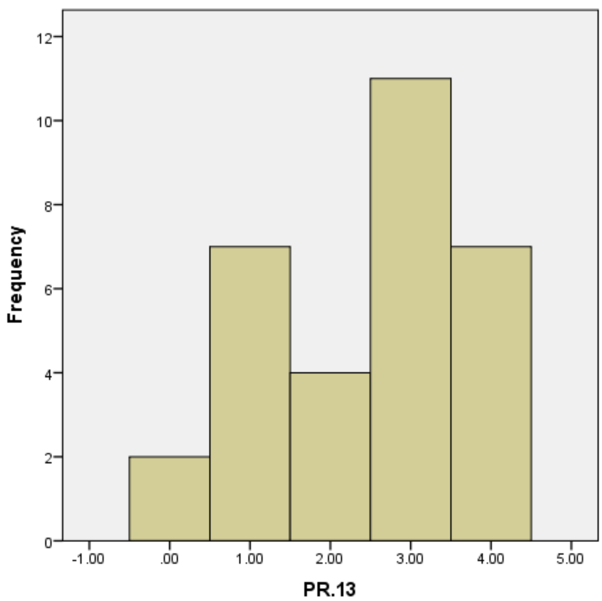
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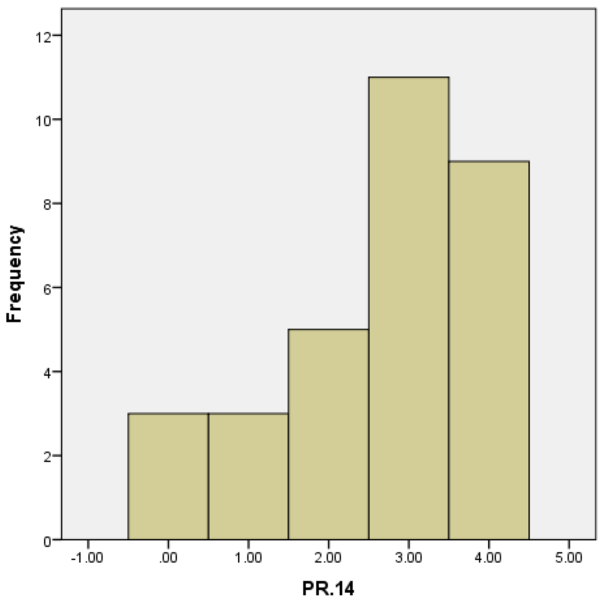
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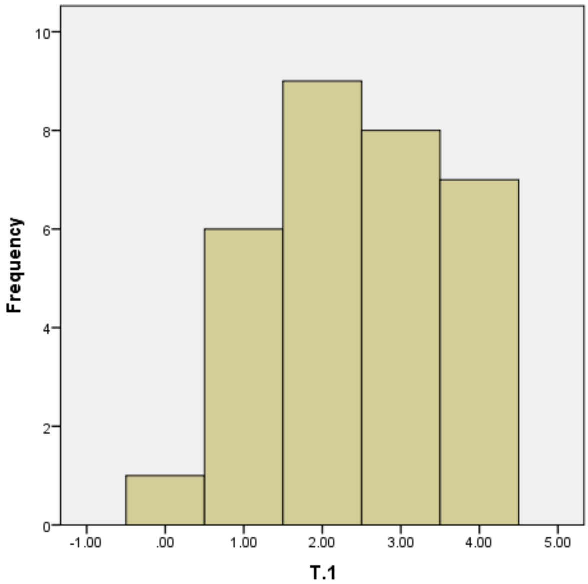
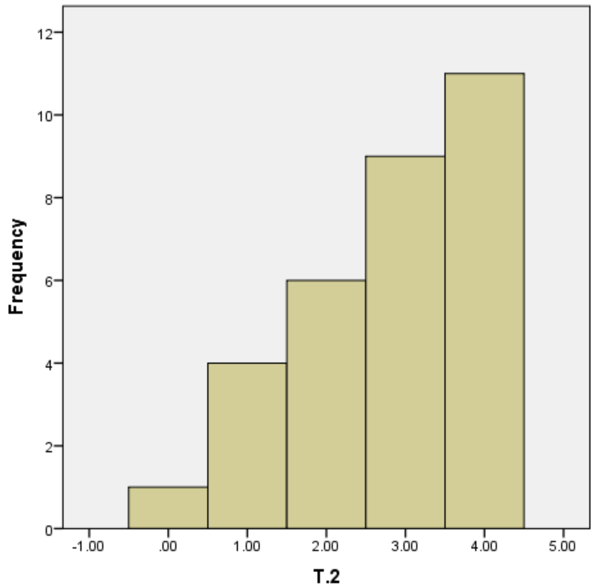
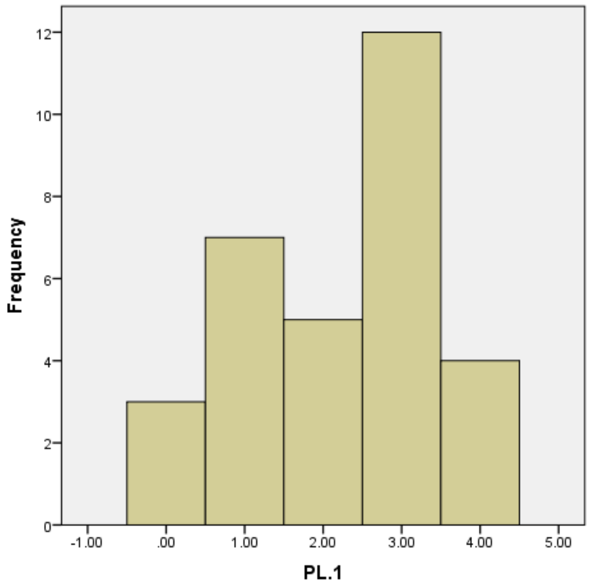
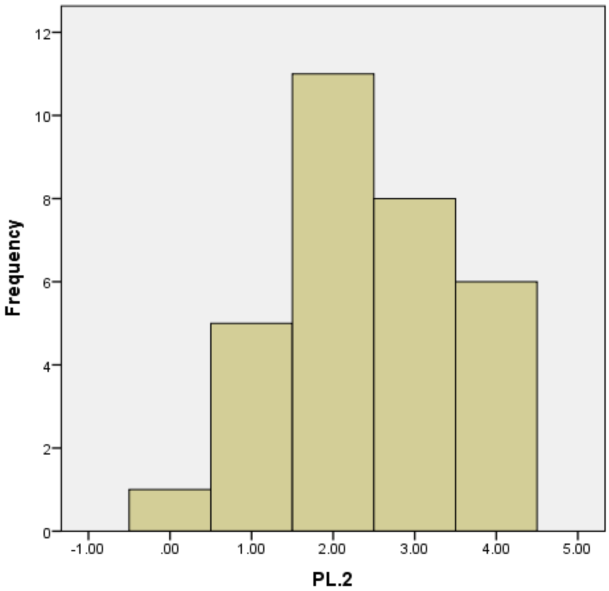
PR.14

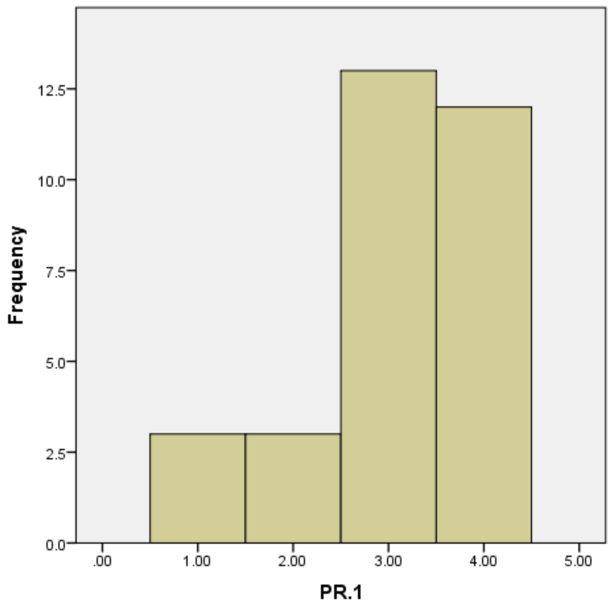
Collaboration Enhancement

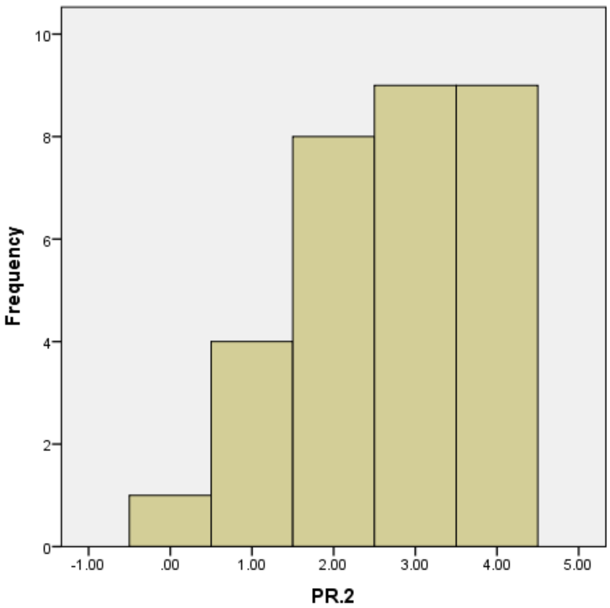


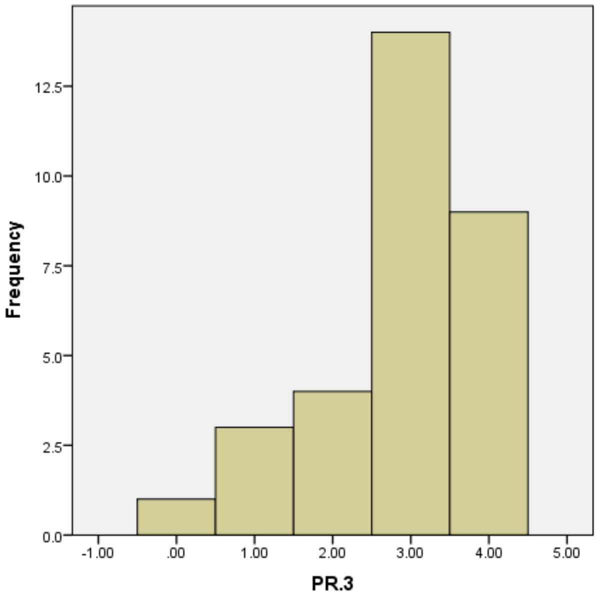








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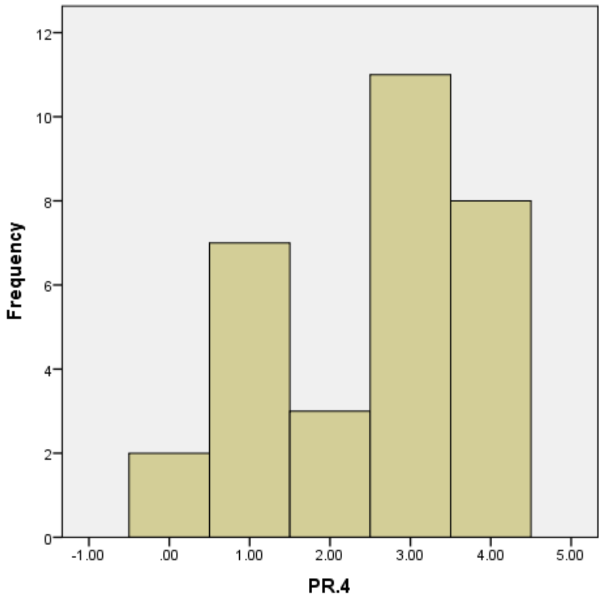
PR.3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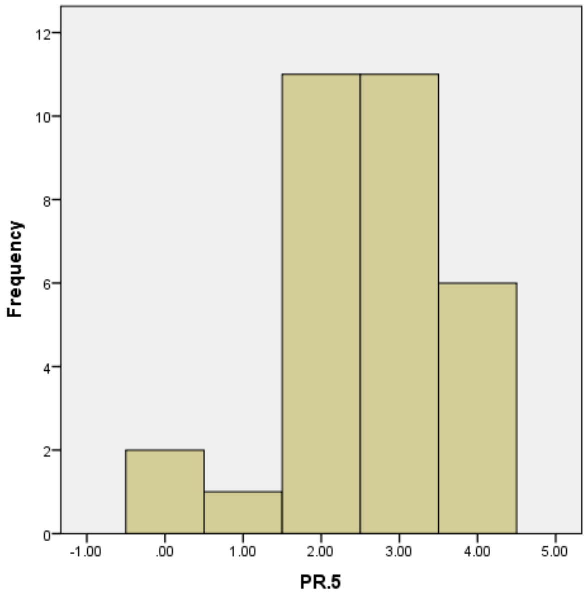
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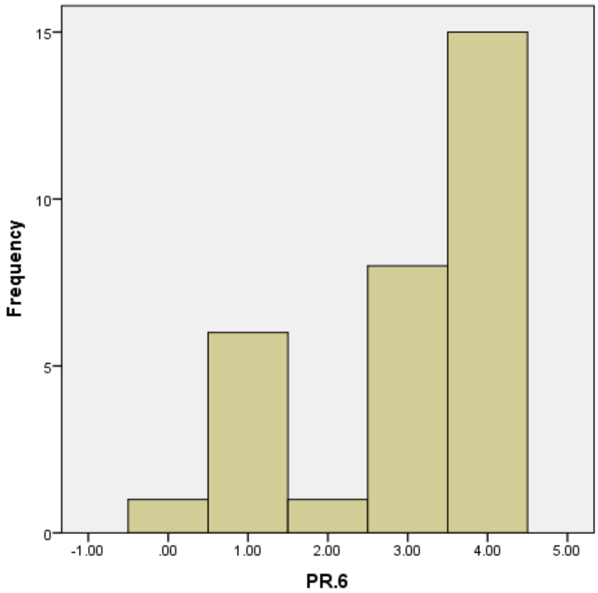
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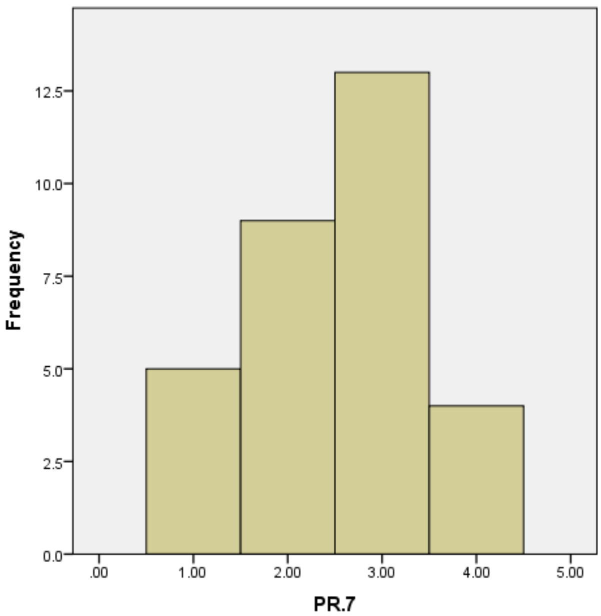
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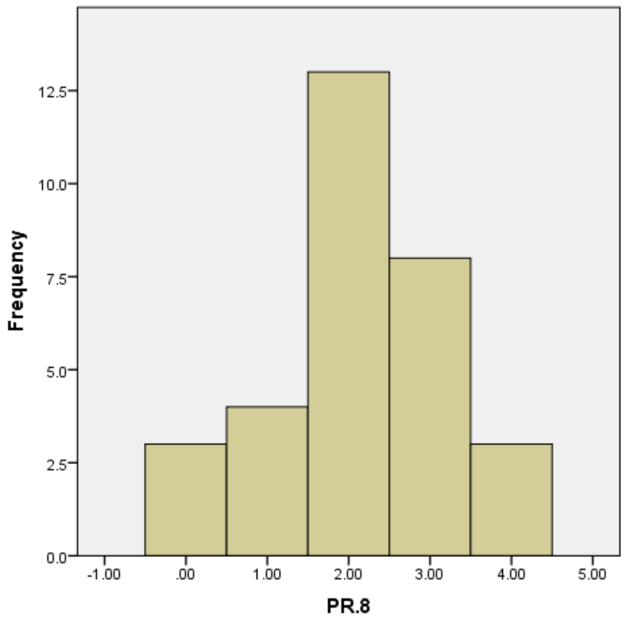
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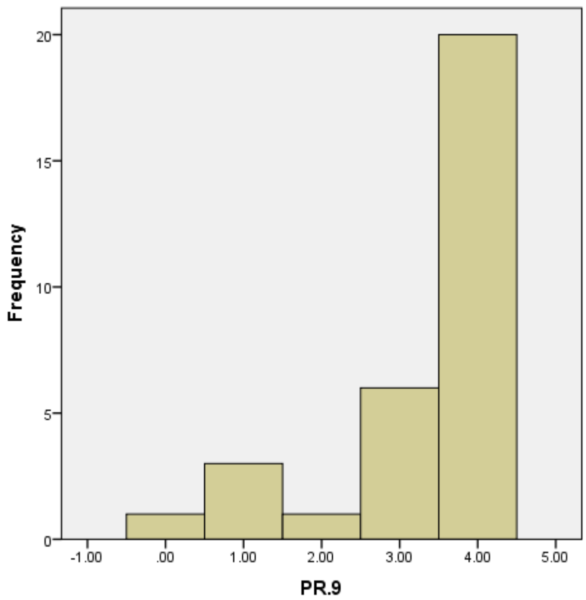
PR.8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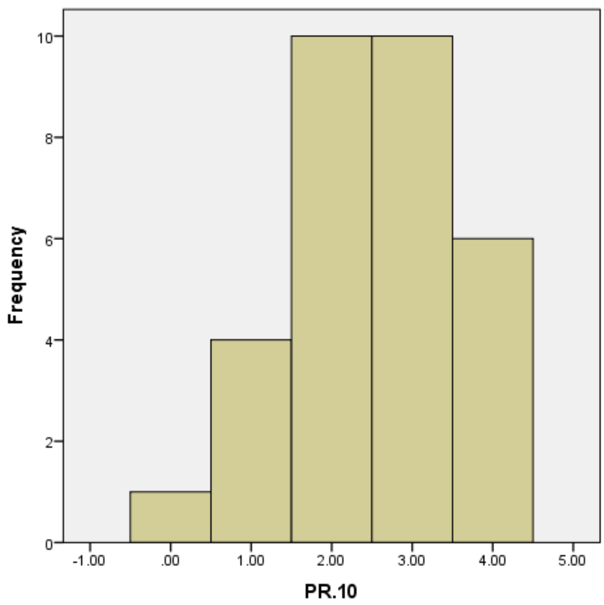
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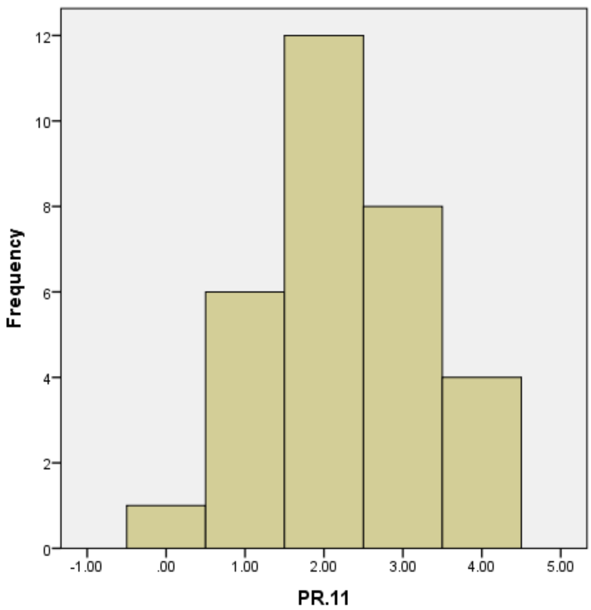
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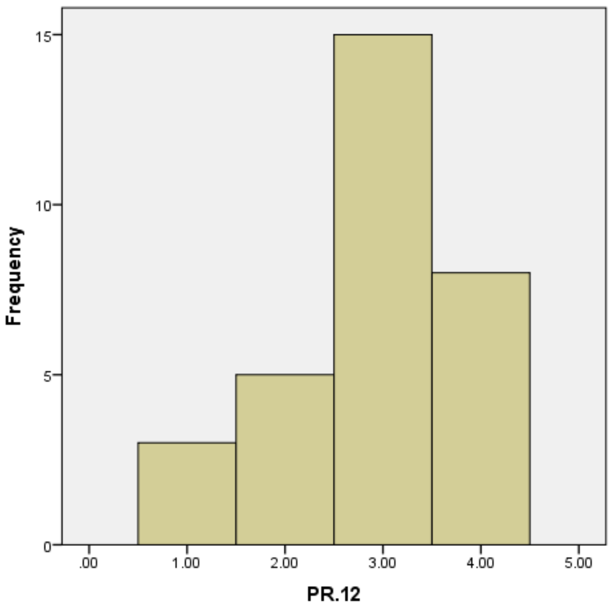
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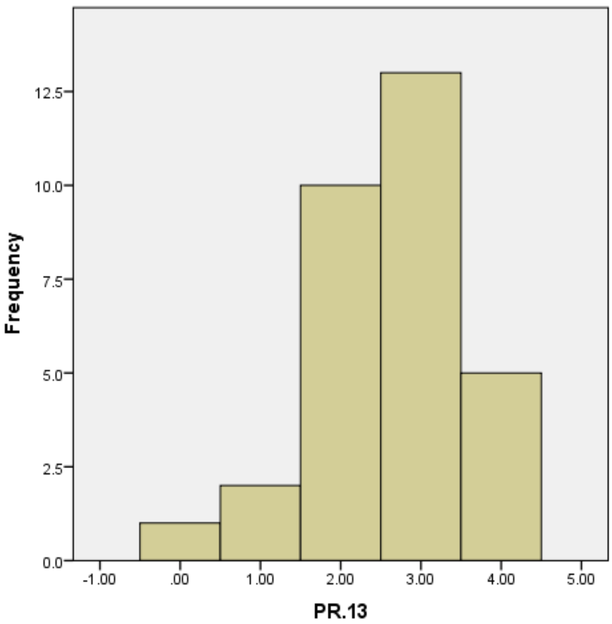
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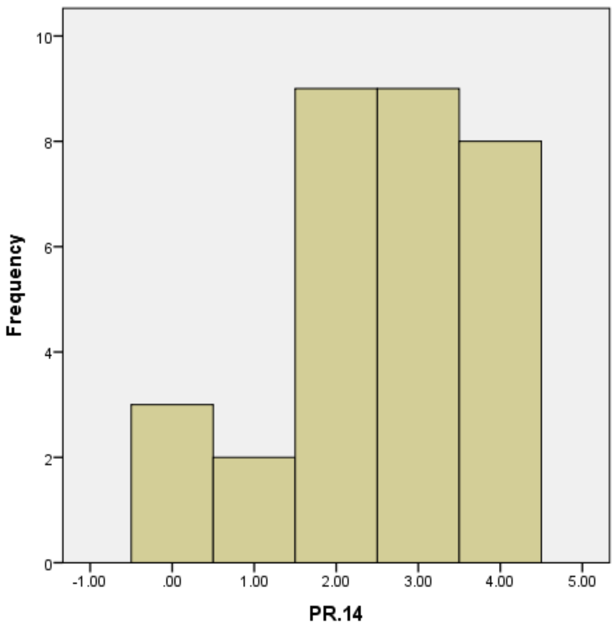
Frequency
PR.14

Appendix B: *Average Weights and Severity Indices for BIM Risks under the Demographic Groups*

Table 38: Ranking of BIM Risks under BIM's Cost Reduction (Nature of Organization)

Risk Code	Consultant			Contractor			Difference between groups
	Weighted Mean	Severity Index	Rank	Weighted Mean	Severity Index	Rank	
PR.1	**2.90**	72.50%	4	**2.73**	68.18%	6	0.17
T.1	**2.40**	60.00%	13	**2.82**	70.45%	3	0.42
PL.1	**1.90**	47.50%	18	**2.64**	65.91%	9	0.74
PR.2	**2.75**	68.75%	8	**2.55**	63.64%	12	0.20
PR.3	**2.95**	73.75%	3	**2.18**	54.55%	17	0.77
PR.4	**2.90**	72.50%	4	**2.64**	65.91%	9	0.26
PL.2	**2.25**	56.25%	17	**2.55**	63.64%	12	0.30
PR.5	**2.60**	65.00%	9	**2.91**	72.73%	2	0.31
T.2	**2.80**	70.00%	7	**2.45**	61.36%	14	0.35
PR.6	**3.15**	78.75%	1	**2.73**	68.18%	6	0.42
PR.7	**2.40**	60.00%	13	**2.27**	56.82%	15	0.13
PR.8	**2.85**	71.25%	6	**2.18**	54.55%	17	0.67
PR.9	**3.05**	76.25%	2	**2.82**	70.45%	3	0.23
PR.10	**2.50**	62.50%	11	**2.64**	65.91%	9	0.14
PR.11	**2.35**	58.75%	16	**2.27**	56.82%	15	0.08
PR.12	**2.50**	62.50%	11	**3.09**	77.27%	1	0.59
PR.13	**2.60**	65.00%	9	**2.73**	68.18%	6	0.13
PR.14	**2.40**	60.00%	13	**2.82**	70.45%	3	0.42
Average	2.63	65.63%		2.61	65.28%		0.01

Table 39: Ranking of BIM Risks under BIM's Time Reduction (Nature of Organization)

Risk Code	Consultant			Contractor			Difference between groups
	Weighted Mean	Severity Index	Rank	Weighted Mean	Severity Index	Rank	
PR.1	**3.35**	83.75%	1	**1.91**	47.73%	16	1.44
T.1	**2.75**	68.75%	9	**2.36**	59.09%	13	0.39
PL.1	**2.00**	50.00%	18	**2.45**	61.36%	10	0.45
PR.2	**2.50**	62.50%	15	**3.27**	81.82%	1	0.77
PR.3	**3.05**	76.25%	6	**2.55**	63.64%	7	0.50
PR.4	**2.95**	73.75%	7	**2.64**	65.91%	6	0.31
PL.2	**2.25**	56.25%	17	**2.55**	63.64%	7	0.30
PR.5	**3.15**	78.75%	5	**3.27**	81.82%	1	0.12
T.2	**3.30**	82.50%	2	**2.36**	59.09%	13	0.94
PR.6	**3.30**	82.50%	2	**2.45**	61.36%	10	0.85
PR.7	**2.60**	65.00%	14	**2.55**	63.64%	7	0.05
PR.8	**2.50**	62.50%	15	**2.73**	68.18%	4	0.23
PR.9	**3.25**	81.25%	4	**2.73**	68.18%	4	0.52
PR.10	**2.90**	72.50%	8	**1.82**	45.45%	18	1.08
PR.11	**2.65**	66.25%	13	**2.09**	52.27%	15	0.56
PR.12	**2.70**	67.50%	12	**3.09**	77.27%	3	0.39
PR.13	**2.75**	68.75%	9	**1.91**	47.73%	16	0.84
PR.14	**2.75**	68.75%	9	**2.45**	61.36%	10	0.30
Average	2.82	70.42%		2.51	62.75%		0.31

Table 40: Ranking of BIM Risks under BIM's Collaboration Improvement (Nature of Organization)

Risk Code	Consultant			Contractor			Difference between groups
	Weighted Mean	Severity Index	Rank	Weighted Mean	Severity Index	Rank	
PR.1	**3.35**	83.75%	2	**2.64**	65.91%	7	0.71
T.1	**2.55**	63.75%	10	**2.27**	56.82%	16	0.28
PL.1	**2.10**	52.50%	17	**2.45**	61.36%	12	0.35
PR.2	**2.25**	56.25%	15	**3.45**	86.36%	1	1.20
PR.3	**2.95**	73.75%	4	**2.73**	68.18%	5	0.22
PR.4	**2.80**	70.00%	7	**2.00**	50.00%	18	0.80
PL.2	**2.40**	60.00%	14	**2.45**	61.36%	12	0.05
PR.5	**2.45**	61.25%	13	**2.82**	70.45%	4	0.37
T.2	**2.85**	71.25%	5	**2.73**	68.18%	5	0.12
PR.6	**3.15**	78.75%	3	**2.64**	65.91%	7	0.51
PR.7	**2.50**	62.50%	12	**2.55**	63.64%	10	0.05
PR.8	**2.10**	52.50%	17	**2.18**	54.55%	17	0.08
PR.9	**3.50**	87.50%	1	**3.00**	75.00%	2	0.50
PR.10	**2.60**	65.00%	8	**2.36**	59.09%	14	0.24
PR.11	**2.20**	55.00%	16	**2.36**	59.09%	14	0.16
PR.12	**2.85**	71.25%	5	**3.00**	75.00%	2	0.15
PR.13	**2.60**	65.00%	8	**2.64**	65.91%	7	0.04
PR.14	**2.55**	63.75%	10	**2.55**	63.64%	10	0.00
Average	2.65	66.32%		2.60	65.03%		0.05

Table 41: Ranking of BIM Risks under BIM's Cost Reduction (Size of Organization)

Risk Code	More than 100 Employees			Less than 100 Employees			Difference between groups
	Weighted Mean	Severity Index	Rank	Weighted Mean	Severity Index	Rank	
PR.1	**3.04**	76.09%	1	**2.25**	56.25%	14	0.79
T.1	**2.65**	66.30%	7	**2.25**	56.25%	14	0.40
PL.1	**2.13**	53.26%	18	**2.25**	56.25%	14	0.12
PR.2	**2.61**	65.22%	10	**2.88**	71.88%	2	0.27
PR.3	**2.61**	65.22%	10	**2.88**	71.88%	2	0.27
PR.4	**2.91**	72.83%	3	**2.50**	62.50%	11	0.41
PL.2	**2.35**	58.70%	16	**2.38**	59.38%	12	0.03
PR.5	**2.70**	67.39%	6	**2.75**	68.75%	5	0.05
T.2	**2.65**	66.30%	7	**2.75**	68.75%	5	0.10
PR.6	**2.87**	71.74%	4	**3.38**	84.38%	1	0.51
PR.7	**2.39**	59.78%	15	**2.25**	56.25%	14	0.14
PR.8	**2.61**	65.22%	10	**2.63**	65.63%	7	0.02
PR.9	**3.00**	75.00%	2	**2.88**	71.88%	2	0.13
PR.10	**2.61**	65.22%	10	**2.38**	59.38%	12	0.23
PR.11	**2.22**	55.43%	17	**2.63**	65.63%	7	0.41
PR.12	**2.87**	71.74%	4	**2.25**	56.25%	14	0.62
PR.13	**2.65**	66.30%	7	**2.63**	65.63%	7	0.03
PR.14	**2.52**	63.04%	14	**2.63**	65.63%	7	0.10
Average	2.63	65.82%		2.58	64.58%		0.05

Table 42: **Ranking of BIM Risks under BIM's Time Reduction (Size of Organization)**

Risk Code	More than 100 Employees			Less than 100 Employees			Difference between groups
	Weighted Mean	Severity Index	Rank	Weighted Mean	Severity Index	Rank	
PR.1	**2.70**	67.39%	9	**3.25**	81.25%	6	0.55
T.1	**2.35**	58.70%	15	**3.38**	84.38%	3	1.03
PL.1	**2.04**	51.09%	18	**2.50**	62.50%	15	0.46
PR.2	**2.87**	71.74%	3	**2.50**	62.50%	15	0.37
PR.3	**2.78**	69.57%	5	**3.13**	78.13%	7	0.34
PR.4	**2.78**	69.57%	5	**3.00**	75.00%	8	0.22
PL.2	**2.43**	60.87%	13	**2.13**	53.13%	18	0.31
PR.5	**3.13**	78.26%	1	**3.38**	84.38%	3	0.24
T.2	**2.78**	69.57%	5	**3.50**	87.50%	2	0.72
PR.6	**2.78**	69.57%	5	**3.63**	90.63%	1	0.84
PR.7	**2.57**	64.13%	12	**2.63**	65.63%	14	0.06
PR.8	**2.70**	67.39%	9	**2.25**	56.25%	17	0.45
PR.9	**2.96**	73.91%	2	**3.38**	84.38%	3	0.42
PR.10	**2.39**	59.78%	14	**2.88**	71.88%	10	0.48
PR.11	**2.26**	56.52%	17	**3.00**	75.00%	8	0.74
PR.12	**2.83**	70.65%	4	**2.88**	71.88%	10	0.05
PR.13	**2.30**	57.61%	16	**2.88**	71.88%	10	0.57
PR.14	**2.61**	65.22%	11	**2.75**	68.75%	13	0.14
Average	2.63	65.64%		2.94	73.61%		0.32

Table 43: **Ranking of BIM Risks under BIM's Collaboration Improvement (Size of Organization)**

Risk Code	More than 100 Employees			Less than 100 Employees			Difference between groups
	Weighted Mean	Severity Index	Rank	Weighted Mean	Severity Index	Rank	
PR.1	**3.00**	75.00%	2	**3.38**	84.38%	1	0.24
T.1	**2.30**	57.61%	15	**2.88**	71.88%	7	0.34
PL.1	**2.17**	54.35%	18	**2.38**	59.38%	14	0.45
PR.2	**2.70**	67.39%	6	**2.63**	65.63%	12	0.05
PR.3	**2.78**	69.57%	5	**3.13**	78.13%	4	0.34
PR.4	**2.39**	59.78%	14	**2.88**	71.88%	7	0.44
PL.2	**2.43**	60.87%	13	**2.38**	59.38%	14	0.38
PR.5	**2.52**	63.04%	9	**2.75**	68.75%	9	0.17
T.2	**2.70**	67.39%	6	**3.13**	78.13%	4	0.07
PR.6	**2.83**	70.65%	4	**3.38**	84.38%	1	0.23
PR.7	**2.52**	63.04%	9	**2.50**	62.50%	13	0.02
PR.8	**2.22**	55.43%	16	**1.88**	46.88%	18	0.34
PR.9	**3.30**	82.61%	1	**3.38**	84.38%	1	0.14
PR.10	**2.61**	65.22%	8	**2.25**	56.25%	17	0.36
PR.11	**2.22**	55.43%	16	**2.38**	59.38%	14	0.16
PR.12	**2.96**	73.91%	3	**2.75**	68.75%	9	0.31
PR.13	**2.48**	61.96%	11	**3.00**	75.00%	6	0.13
PR.14	**2.48**	61.96%	11	**2.75**	68.75%	9	0.40
Average	2.59	64.73%		2.76	69.10%		0.17

Table 44: **Ranking of BIM Risks under BIM's Cost Reduction (Position)**

Risk Code	Architect			Other (Eng, Draftsman., Manager)			Difference between groups
	Weighted Mean	Severity Index	Rank	Weighted Mean	Severity Index	Rank	
PR.1	2.30	57.50%	11	3.10	77.38%	2	0.80
T.1	2.20	55.00%	13	2.71	67.86%	8	0.51
PL.1	2.30	57.50%	11	2.10	52.38%	18	0.20
PR.2	2.70	67.50%	4	2.67	66.67%	10	0.03
PR.3	2.80	70.00%	2	2.62	65.48%	13	0.18
PR.4	2.80	70.00%	2	2.81	70.24%	6	0.01
PL.2	2.20	55.00%	13	2.43	60.71%	16	0.23
PR.5	2.60	65.00%	6	2.76	69.05%	7	0.16
T.2	2.70	67.50%	4	2.67	66.67%	10	0.03
PR.6	3.10	77.50%	1	2.95	73.81%	4	0.15
PR.7	1.90	47.50%	17	2.57	64.29%	14	0.67
PR.8	2.50	62.50%	7	2.67	66.67%	10	0.17
PR.9	2.50	62.50%	7	3.19	79.76%	1	0.69
PR.10	1.80	45.00%	18	2.90	72.62%	5	1.10
PR.11	2.10	52.50%	15	2.43	60.71%	16	0.33
PR.12	2.10	52.50%	15	3.00	75.00%	3	0.90
PR.13	2.50	62.50%	7	2.71	67.86%	8	0.21
PR.14	2.50	62.50%	7	2.57	64.29%	14	0.07
Average	2.42	60.56%		2.71	67.86%		0.29

Table 45: **Ranking of BIM Risks under BIM's Time Reduction (Position)**

Risk Code	Architect			Other (Eng, Draftsman., Manager)			Difference between groups
	Weighted Mean	Severity Index	Rank	Weighted Mean	Severity Index	Rank	
PR.1	3.30	82.50%	2	2.62	65.48%	10	0.68
T.1	3.00	75.00%	7	2.43	60.71%	14	0.57
PL.1	2.40	60.00%	15	2.05	51.19%	18	0.35
PR.2	2.30	57.50%	16	3.00	75.00%	2	0.70
PR.3	3.10	77.50%	5	2.76	69.05%	8	0.34
PR.4	2.80	70.00%	9	2.86	71.43%	6	0.06
PL.2	2.20	55.00%	17	2.43	60.71%	14	0.23
PR.5	3.20	80.00%	4	3.19	79.76%	1	0.01
T.2	3.10	77.50%	5	2.90	72.62%	4	0.20
PR.6	3.50	87.50%	1	2.76	69.05%	8	0.74
PR.7	2.50	62.50%	14	2.62	65.48%	10	0.12
PR.8	2.10	52.50%	18	2.81	70.24%	7	0.71
PR.9	3.30	82.50%	2	2.95	73.81%	3	0.35
PR.10	2.60	65.00%	13	2.48	61.90%	12	0.12
PR.11	2.70	67.50%	11	2.33	58.33%	16	0.37
PR.12	2.70	67.50%	11	2.90	72.62%	4	0.20
PR.13	2.80	70.00%	9	2.29	57.14%	17	0.51
PR.14	3.00	75.00%	7	2.48	61.90%	12	0.52
Average	2.81	70.28%		2.66	66.47%		0.15

Table 46: Ranking of BIM Risks under BIM's Collaboration Improvement (Position)

Risk Code	Architect			Other (Eng, Draftsman., Manager)			Difference between groups
	Weighted Mean	Severity Index	Rank	Weighted Mean	Severity Index	Rank	
PR.1	2.90	72.50%	5	3.19	79.76%	2	0.29
T.1	2.50	62.50%	11	2.43	60.71%	14	0.07
PL.1	2.30	57.50%	14	2.19	54.76%	18	0.11
PR.2	2.30	57.50%	14	2.86	71.43%	6	0.56
PR.3	3.00	75.00%	3	2.81	70.24%	7	0.19
PR.4	3.00	75.00%	3	2.29	57.14%	16	0.71
PL.2	2.10	52.50%	16	2.57	64.29%	9	0.47
PR.5	2.70	67.50%	6	2.52	63.10%	12	0.18
T.2	2.60	65.00%	8	2.90	72.62%	4	0.30
PR.6	3.10	77.50%	2	2.90	72.62%	4	0.20
PR.7	2.40	60.00%	12	2.57	64.29%	9	0.17
PR.8	1.90	47.50%	18	2.24	55.95%	17	0.34
PR.9	3.30	82.50%	1	3.33	83.33%	1	0.03
PR.10	2.40	60.00%	12	2.57	64.29%	9	0.17
PR.11	2.00	50.00%	17	2.38	59.52%	15	0.38
PR.12	2.70	67.50%	6	3.00	75.00%	3	0.30
PR.13	2.60	65.00%	8	2.62	65.48%	8	0.02
PR.14	2.60	65.00%	8	2.52	63.10%	12	0.08
Average	2.58	64.44%		2.66	66.53%		0.08

Table 47: Ranking of BIM Risks under BIM's Cost Reduction (General Experience)

Risk Code	Less than 5 years experience			More than 5 years experience			Difference between groups
	Weighted Mean	Severity Index	Rank	Weighted Mean	Severity Index	Rank	
PR.1	2.36	58.93%	12	3.24	80.88%	1	0.88
T.1	2.43	60.71%	8	2.65	66.18%	12	0.22
PL.1	2.43	60.71%	8	1.94	48.53%	18	0.49
PR.2	2.71	67.86%	3	2.65	66.18%	12	0.07
PR.3	2.57	64.29%	5	2.76	69.12%	8	0.19
PR.4	2.29	57.14%	14	3.24	80.88%	1	0.95
PL.2	2.07	51.79%	16	2.59	64.71%	15	0.52
PR.5	2.79	69.64%	2	2.65	66.18%	12	0.14
T.2	2.57	64.29%	5	2.76	69.12%	8	0.19
PR.6	2.86	71.43%	1	3.12	77.94%	4	0.26
PR.7	2.07	51.79%	16	2.59	64.71%	15	0.52
PR.8	2.43	60.71%	8	2.76	69.12%	8	0.34
PR.9	2.64	66.07%	4	3.24	80.88%	1	0.59
PR.10	2.00	50.00%	18	3.00	75.00%	5	1.00
PR.11	2.29	57.14%	14	2.35	58.82%	17	0.07
PR.12	2.50	62.50%	7	2.88	72.06%	6	0.38
PR.13	2.43	60.71%	8	2.82	70.59%	7	0.39
PR.14	2.36	58.93%	12	2.71	67.65%	11	0.35
Average	2.43	60.81%		2.77	69.36%		0.34

Table 48: Ranking of BIM Risks under BIM's Time Reduction (General Experience)

Risk Code	Less than 5 years experience			More than 5 years experience			Difference between groups
	Weighted Mean	Severity Index	Rank	Weighted Mean	Severity Index	Rank	
PR.1	**2.71**	67.86%	7	**2.94**	73.53%	5	0.23
T.1	**2.79**	69.64%	5	**2.47**	61.76%	15	0.32
PL.1	**2.29**	57.14%	17	**2.06**	51.47%	18	0.23
PR.2	**2.57**	64.29%	11	**2.94**	73.53%	5	0.37
PR.3	**2.79**	69.64%	5	**2.94**	73.53%	5	0.16
PR.4	**2.50**	62.50%	13	**3.12**	77.94%	1	0.62
PL.2	**2.00**	50.00%	18	**2.65**	66.18%	11	0.65
PR.5	**3.36**	83.93%	1	**3.06**	76.47%	2	0.30
T.2	**2.93**	73.21%	4	**3.00**	75.00%	4	0.07
PR.6	**3.07**	76.79%	2	**2.94**	73.53%	5	0.13
PR.7	**2.57**	64.29%	11	**2.59**	64.71%	13	0.02
PR.8	**2.43**	60.71%	14	**2.71**	67.65%	10	0.28
PR.9	**3.07**	76.79%	2	**3.06**	76.47%	2	0.01
PR.10	**2.36**	58.93%	16	**2.65**	66.18%	11	0.29
PR.11	**2.64**	66.07%	10	**2.29**	57.35%	17	0.35
PR.12	**2.71**	67.86%	7	**2.94**	73.53%	5	0.23
PR.13	**2.43**	60.71%	14	**2.47**	61.76%	15	0.04
PR.14	**2.71**	67.86%	7	**2.59**	64.71%	13	0.13
Average	2.66	66.57%		2.75	68.63%		0.08

Table 49: Ranking of BIM Risks under BIM's Collaboration Improvement (General Experience)

Risk Code	Less than 5 years experience			More than 5 years experience			Difference between groups
	Weighted Mean	Severity Index	Rank	Weighted Mean	Severity Index	Rank	
PR.1	**3.07**	76.79%	2	**3.12**	77.94%	3	0.05
T.1	**2.21**	55.36%	14	**2.65**	66.18%	10	0.43
PL.1	**2.43**	60.71%	11	**2.06**	51.47%	18	0.37
PR.2	**2.79**	69.64%	4	**2.59**	64.71%	11	0.20
PR.3	**2.71**	67.86%	6	**3.00**	75.00%	4	0.29
PR.4	**2.43**	60.71%	11	**2.59**	64.71%	11	0.16
PL.2	**2.00**	50.00%	17	**2.76**	69.12%	8	0.76
PR.5	**2.79**	69.64%	4	**2.41**	60.29%	14	0.37
T.2	**2.64**	66.07%	7	**2.94**	73.53%	5	0.30
PR.6	**2.64**	66.07%	7	**3.24**	80.88%	2	0.59
PR.7	**2.64**	66.07%	7	**2.41**	60.29%	14	0.23
PR.8	**1.93**	48.21%	18	**2.29**	57.35%	17	0.37
PR.9	**3.14**	78.57%	1	**3.47**	86.76%	1	0.33
PR.10	**2.14**	53.57%	15	**2.82**	70.59%	7	0.68
PR.11	**2.07**	51.79%	16	**2.41**	60.29%	14	0.34
PR.12	**2.93**	73.21%	3	**2.88**	72.06%	6	0.05
PR.13	**2.43**	60.71%	11	**2.76**	69.12%	8	0.34
PR.14	**2.57**	64.29%	10	**2.53**	63.24%	13	0.04
Average	2.53	63.29%		2.72	67.97%		0.19

Table 50: Ranking of BIM Risks under BIM's Cost Reduction (BIM Experience)

Risk Code	No BIM Experience			Less than 5 years			More than 5 years			Average Difference between groups
	Weighted Mean	Severity Index	Rank	Weighted Mean	Severity Index	Rank	Weighted Mean	Severity Index	Rank	
PR.1	3.07	76.79%	2	2.77	69.23%	6	3.22	80.56%	1	0.30
T.1	2.21	55.36%	14	2.62	65.38%	7	2.44	61.11%	12	0.27
PL.1	2.43	60.71%	11	1.92	48.08%	18	2.00	50.00%	18	0.34
PR.2	2.79	69.64%	4	2.54	63.46%	10	2.78	69.44%	6	0.17
PR.3	2.71	67.86%	6	2.54	63.46%	10	2.67	66.67%	9	0.12
PR.4	2.43	60.71%	11	3.00	75.00%	2	2.89	72.22%	4	0.38
PL.2	2.00	50.00%	17	2.62	65.38%	7	2.33	58.33%	14	0.41
PR.5	2.79	69.64%	4	2.38	59.62%	16	2.89	72.22%	4	0.33
T.2	2.64	66.07%	7	2.46	61.54%	14	2.78	69.44%	6	0.21
PR.6	2.64	66.07%	7	3.23	80.77%	1	2.78	69.44%	6	0.39
PR.7	2.64	66.07%	7	2.15	53.85%	17	2.67	66.67%	9	0.34
PR.8	1.93	48.21%	18	2.62	65.38%	7	2.44	61.11%	12	0.46
PR.9	3.14	78.57%	1	2.85	71.15%	4	3.22	80.56%	1	0.25
PR.10	2.14	53.57%	15	2.54	63.46%	10	3.11	77.78%	3	0.65
PR.11	2.07	51.79%	16	2.46	61.54%	14	2.33	58.33%	14	0.26
PR.12	2.93	73.21%	3	2.92	73.08%	3	2.56	63.89%	11	0.25
PR.13	2.43	60.71%	11	2.85	71.15%	4	2.33	58.33%	14	0.34
PR.14	2.57	64.29%	10	2.54	63.46%	10	2.22	55.56%	17	0.23
Average	2.53	63.29%		2.61	65.28%		2.65	66.20%		0.08

Table 51: Ranking of BIM Risks under BIM's Time Reduction (BIM Experience)

Risk Code	No BIM Experience			Less than 5 years			More than 5 years			Average Difference between groups
	Weighted Mean	Severity Index	Rank	Weighted Mean	Severity Index	Rank	Weighted Mean	Severity Index	Rank	
PR.1	2.89	72.22%	8	2.69	67.31%	7	3.00	75.00%	2	0.21
T.1	2.89	72.22%	8	2.62	65.38%	10	2.33	58.33%	13	0.37
PL.1	2.33	58.33%	17	1.92	48.08%	18	2.33	58.33%	13	0.27
PR.2	2.67	66.67%	12	2.77	69.23%	5	2.89	72.22%	4	0.15
PR.3	3.22	80.56%	4	2.69	67.31%	7	2.78	69.44%	9	0.35
PR.4	2.56	63.89%	13	3.23	80.77%	1	2.56	63.89%	10	0.45
PL.2	2.22	55.56%	18	2.62	65.38%	10	2.11	52.78%	16	0.34
PR.5	3.56	88.89%	1	3.00	75.00%	2	3.11	77.78%	1	0.37
T.2	3.33	83.33%	2	2.77	69.23%	5	2.89	72.22%	4	0.38
PR.6	3.22	80.56%	4	2.92	73.08%	4	2.89	72.22%	4	0.22
PR.7	2.56	63.89%	13	2.38	59.62%	17	2.89	72.22%	4	0.33
PR.8	2.78	69.44%	10	2.46	61.54%	14	2.56	63.89%	10	0.21
PR.9	3.33	83.33%	2	3.00	75.00%	2	2.89	72.22%	4	0.30
PR.10	2.44	61.11%	16	2.54	63.46%	13	2.56	63.89%	10	0.07
PR.11	2.56	63.89%	13	2.69	67.31%	7	2.00	50.00%	18	0.46
PR.12	3.00	75.00%	7	2.62	65.38%	10	3.00	75.00%	2	0.25
PR.13	2.78	69.44%	10	2.46	61.54%	14	2.11	52.78%	16	0.44
PR.14	3.22	80.56%	4	2.46	61.54%	14	2.33	58.33%	13	0.59
Average	2.86	71.60%		2.66	66.45%		2.62	65.59%		0.16

Table 52: **Ranking of BIM Risks under BIM's Collaboration Improvement (BIM Experience)**

Risk Code	No BIM Experience			Less than 5 years			More than 5 years			Average Difference between groups
	Weighted Mean	Severity Index	Rank	Weighted Mean	Severity Index	Rank	Weighted Mean	Severity Index	Rank	
PR.1	**3.07**	76.79%	2	**3.12**	77.94%	3	**3.33**	83.33%	2	0.18
T.1	**2.21**	55.36%	14	**2.65**	66.18%	10	**2.33**	58.33%	13	0.29
PL.1	**2.43**	60.71%	11	**2.06**	51.47%	18	**2.33**	58.33%	13	0.24
PR.2	**2.79**	69.64%	4	**2.59**	64.71%	11	**2.44**	61.11%	11	0.23
PR.3	**2.71**	67.86%	6	**3.00**	75.00%	4	**3.00**	75.00%	4	0.19
PR.4	**2.43**	60.71%	11	**2.59**	64.71%	11	**2.11**	52.78%	17	0.32
PL.2	**2.00**	50.00%	17	**2.76**	69.12%	8	**2.44**	61.11%	11	0.51
PR.5	**2.79**	69.64%	4	**2.41**	60.29%	14	**2.56**	63.89%	7	0.25
T.2	**2.64**	66.07%	7	**2.94**	73.53%	5	**2.67**	66.67%	6	0.20
PR.6	**2.64**	66.07%	7	**3.24**	80.88%	2	**3.33**	83.33%	2	0.46
PR.7	**2.64**	66.07%	7	**2.41**	60.29%	14	**2.56**	63.89%	7	0.15
PR.8	**1.93**	48.21%	18	**2.29**	57.35%	17	**2.33**	58.33%	13	0.27
PR.9	**3.14**	78.57%	1	**3.47**	86.76%	1	**3.67**	91.67%	1	0.35
PR.10	**2.14**	53.57%	15	**2.82**	70.59%	7	**2.78**	69.44%	5	0.45
PR.11	**2.07**	51.79%	16	**2.41**	60.29%	14	**2.56**	63.89%	7	0.32
PR.12	**2.93**	73.21%	3	**2.88**	72.06%	6	**2.56**	63.89%	7	0.25
PR.13	**2.43**	60.71%	11	**2.76**	69.12%	8	**2.33**	58.33%	13	0.29
PR.14	**2.57**	64.29%	10	**2.53**	63.24%	13	**2.00**	50.00%	18	0.38
Average	2.53	63.29%		2.72	67.97%		2.63	65.74%		0.13

Appendix C: *Independent T-Tests for the Impact of BIM Risks on its Advantages*

Table 53: Independent T-Test for the Impact of BIM Risks on its Cost Reduction (Type of Organization Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference: Lower	Upper
PR.1	Equal variances assumed	0.001	.977	0.425	29	.674	0.17273	.40634	-.65834	1.00379
	Equal variances not assumed			0.438	22.653	.665	0.17273	.39395	-.64290	0.98836
T.1	Equal variances assumed	2.252	.144	-.994	29	.329	-.41818	.42076	-1.27874	0.44238
	Equal variances not assumed			-1.052	24.295	.303	-.41818	.39766	-1.23837	0.40201
PL.1	Equal variances assumed	.058	.811	-1.752	29	.090	-.73636	.42024	-1.59585	.12312
	Equal variances not assumed			-1.691	18.706	.107	-.73636	.43543	-1.64870	.17597
PR.2	Equal variances assumed	0.372	.547	0.486	29	.631	.20455	.42100	-0.65650	1.06559
	Equal variances not assumed			0.485	20.563	.633	.20455	.42214	-0.67448	1.08357
PR.3	Equal variances assumed	2.356	.136	2.137	29	.041	.76818	.35942	.03309	1.50327
	Equal variances not assumed			2.016	17.544	.059	.76818	.38096	-.03367	1.57003
PR.4	Equal variances assumed	2.005	.167	.665	29	.511	.26364	.39644	-.54717	1.07445
	Equal variances not assumed			.623	17.204	.541	.26364	.42317	-.62837	1.15564
PL.2	Equal variances assumed	2.562	.120	-.768	29	.449	-.29545	.38482	-1.08250	.49159
	Equal variances not assumed			-.706	16.326	.490	-.29545	.41873	-1.18167	.59077
PR.5	Equal variances assumed	0.297	.590	-.814	29	.423	-.30909	.37994	-1.08616	.46797
	Equal variances not assumed			-.802	19.864	.432	-.30909	.38555	-1.11368	.49550
T.2	Equal variances assumed	1.610	.215	0.765	29	.450	.34545	.45136	-.57767	1.26858
	Equal variances not assumed			0.699	16.057	.495	.34545	.49419	-.70187	1.39278
PR.6	Equal variances assumed	2.365	.135	1.060	29	.298	.42273	.39880	-.39291	1.23837
	Equal variances not assumed			0.968	16.057	.347	.42273	.43665	-.50265	1.34811
PR.7	Equal variances assumed	.247	.623	.365	29	.718	.12727	.34840	-.58529	.83984
	Equal variances not assumed			.370	21.435	.715	.12727	.34437	-.58800	.84255
PR.8	Equal variances assumed	5.503	**.026**	1.745	29	.092	.66818	.38298	-0.11510	1.45146
	Equal variances not assumed			1.520	14.226	**.151**	.66818	.43972	-0.27353	1.60989
PR.9	Equal variances assumed	1.101	.303	0.622	29	.539	.23182	.37269	-.53042	0.99406
	Equal variances not assumed			0.657	24.168	.517	.23182	.35292	-.49631	0.95994
PR.10	Equal variances assumed	.515	.479	-0.311	29	.758	-0.13636	.43835	-1.03289	0.76016
	Equal variances not assumed			-0.329	24.190	.745	-0.13636	.41495	-.99242	0.71970
PR.11	Equal variances assumed	.002	.966	0.170	29	.867	.07727	.45567	-.85467	1.00921
	Equal variances not assumed			0.171	21.252	.866	.07727	.45173	-.86147	1.01601
PR.12	Equal variances assumed	5.683	**.024**	-1.501	29	.144	-.59091	.39376	-1.39623	.21441
	Equal variances not assumed			-1.737	28.786	**.093**	-.59091	.34012	-1.28675	.10494
PR.13	Equal variances assumed	.003	.957	-0.309	29	.760	-.12727	.41228	-.97048	0.71593
	Equal variances not assumed			-0.308	20.590	.761	-.12727	.41321	-.98764	0.73309
PR.14	Equal variances assumed	.339	.565	-.880	29	.386	-.41818	.47501	-1.38968	0.55332
	Equal variances not assumed			-.912	22.924	.371	-.41818	.45857	-1.36697	0.53061

Table 54: Independent T-Test for the Impact of BIM Risks on its Time Reduction (Type of Organization Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PR.1	Equal variances assumed	1.061	.312	3.574	29	.001	1.44091	.40321	.61626	2.26556
	Equal variances not assumed			3.356	17.318	.004	1.44091	.42936	.53630	2.34552
T.1	Equal variances assumed	.046	.832	.920	29	.365	.38636	.41995	-.47253	1.24526
	Equal variances not assumed			.920	20.693	.368	.38636	.42018	-.48824	1.26096
PL.1	Equal variances assumed	.929	.343	-1.107	29	.278	-.45455	.41078	-1.29468	.38559
	Equal variances not assumed			-1.052	17.948	.307	-.45455	.43187	-1.36207	.45298
PR.2	Equal variances assumed	4.800	**.037**	-2.209	29	.035	-.77273	.34980	-1.48814	-.05732
	Equal variances not assumed			-2.530	28.504	**.017**	-.77273	.30542	-1.39785	-.14761
PR.3	Equal variances assumed	.236	.631	1.555	29	.131	.50455	.32454	-.15922	1.16831
	Equal variances not assumed			1.592	22.175	.126	.50455	.31702	-.15261	1.16170
PR.4	Equal variances assumed	3.611	.067	.735	29	.468	.31364	.42683	-.55934	1.18661
	Equal variances not assumed			.671	16.052	.512	.31364	.46740	-.67695	1.30422
PL.2	Equal variances assumed	1.710	.201	-.744	29	.463	-.29545	.39725	-1.10792	.51701
	Equal variances not assumed			-.695	17.099	.496	-.29545	.42496	-1.19165	.60074
PR.5	Equal variances assumed	2.502	.125	-.407	29	.687	-.12273	.30169	-.73975	.49430
	Equal variances not assumed			-.362	14.986	.723	-.12273	.33921	-.84579	.60033
T.2	Equal variances assumed	1.356	.254	2.216	29	.035	.93636	.42254	.07216	1.80056
	Equal variances not assumed			2.012	15.817	.062	.93636	.46528	-.05092	1.92365
PR.6	Equal variances assumed	4.156	.051	1.944	29	.062	.84545	.43491	-.04403	1.73494
	Equal variances not assumed			1.739	15.212	.102	.84545	.48613	-.18945	1.88036
PR.7	Equal variances assumed	.000	.989	.177	29	.861	.05455	.30803	-.57544	.68454
	Equal variances not assumed			.177	20.738	.861	.05455	.30796	-.58639	.69548
PR.8	Equal variances assumed	.378	.543	-.566	29	.576	-.22727	.40153	-1.04850	.59395
	Equal variances not assumed			-.558	19.867	.583	-.22727	.40744	-1.07754	.62300
PR.9	Equal variances assumed	.268	.609	1.287	29	.208	.52273	.40604	-.30773	1.35318
	Equal variances not assumed			1.187	16.484	.252	.52273	.44025	-.40833	1.45379
PR.10	Equal variances assumed	.076	.785	2.471	29	.020	1.08182	.43774	.18653	1.97710
	Equal variances not assumed			2.470	20.687	.022	1.08182	.43802	.17007	1.99357
PR.11	Equal variances assumed	.003	.959	1.387	29	.176	.55909	.40321	-.26556	1.38374
	Equal variances not assumed			1.404	21.497	.175	.55909	.39814	-.26772	1.38591
PR.12	Equal variances assumed	2.140	.154	-.897	29	.377	-.39091	.43592	-1.28247	.50065
	Equal variances not assumed			-.906	21.327	.375	-.39091	.43163	-1.28769	.50587
PR.13	Equal variances assumed	.690	.413	1.847	29	.075	.84091	.45528	-.09024	1.77206
	Equal variances not assumed			1.967	24.715	.060	.84091	.42746	-.03999	1.72180
PR.14	Equal variances assumed	.105	.748	.609	29	.547	.29545	.48533	-.69716	1.28807
	Equal variances not assumed			.626	22.465	.538	.29545	.47191	-.68206	1.27297

Table 55: Independent T-Test for the Impact of BIM Risks on its Collaboration Improvement (Type of Organization Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PR.1	Equal variances assumed	0.898	.351	2.130	29	.042	0.71364	.33499	.02850	1.39877
	Equal variances not assumed			1.988	17.014	.063	0.71364	.35902	-.04378	1.47105
T.1	Equal variances assumed	.204	.655	.636	29	.530	.27727	.43605	-.61455	1.16909
	Equal variances not assumed			.651	22.132	.522	.27727	.42622	-.60635	1.16090
PL.1	Equal variances assumed	.040	.843	-0.762	29	.452	-.35455	.46514	-1.30586	.59677
	Equal variances not assumed			-0.747	19.554	.464	-.35455	.47458	-1.34595	.63685
PR.2	Equal variances assumed	4.376	**.045**	-3.238	29	.003	-1.20455	.37198	-1.96533	-.44376
	Equal variances not assumed			-3.959	28.259	**.000**	-1.20455	.30423	-1.82748	-.58161
PR.3	Equal variances assumed	.064	.802	0.555	29	.583	.22273	.40123	-.59788	1.04333
	Equal variances not assumed			0.595	25.138	.557	.22273	.37422	-.54777	0.99323
PR.4	Equal variances assumed	9.595	**.004**	1.707	29	.098	.80000	.46864	-.15848	1.75848
	Equal variances not assumed			1.494	14.386	**.157**	.80000	.53562	-.34591	1.94591
PL.2	Equal variances assumed	0.879	.356	-.131	29	.896	-.05455	.41548	-0.90430	.79521
	Equal variances not assumed			-.126	18.243	.901	-.05455	.43431	-0.96612	.85702
PR.5	Equal variances assumed	1.497	.231	-.925	29	.362	-.36818	.39791	-1.18201	.44564
	Equal variances not assumed			-.824	15.033	.423	-.36818	.44685	-1.32043	.58407
T.2	Equal variances assumed	0.551	.464	0.276	29	.785	.12273	.44487	-.78714	1.03260
	Equal variances not assumed			0.259	17.296	.799	.12273	.47395	-.87592	1.12138
PR.6	Equal variances assumed	4.694	**.039**	1.074	29	.292	.51364	.47837	-.46473	1.49200
	Equal variances not assumed			0.966	15.451	**.349**	.51364	.53149	-.61634	1.64361
PR.7	Equal variances assumed	.982	.330	-.129	29	.899	-.04545	.35356	-.76857	.67766
	Equal variances not assumed			-.136	24.438	.893	-.04545	.33340	-.73291	.64200
PR.8	Equal variances assumed	.734	.399	-.197	29	.845	-.08182	.41495	-0.93048	.76685
	Equal variances not assumed			-.180	15.979	.860	-.08182	.45516	-1.04682	.88319
PR.9	Equal variances assumed	.313	.580	1.179	29	.248	.50000	.42401	-.36719	1.36719
	Equal variances not assumed			1.082	16.246	.295	.50000	.46221	-.47863	1.47863
PR.10	Equal variances assumed	.057	.813	0.587	29	.562	0.23636	.40252	-.58688	1.05961
	Equal variances not assumed			0.599	21.916	.556	0.23636	.39480	-.58259	1.05531
PR.11	Equal variances assumed	.655	.425	-0.417	29	.680	-.16364	.39275	-.96689	0.63962
	Equal variances not assumed			-0.403	18.873	.691	-.16364	.40568	-1.01312	0.68585
PR.12	Equal variances assumed	3.663	.066	-.434	29	.667	-.15000	.34538	-0.85638	.55638
	Equal variances not assumed			-.467	25.260	.645	-.15000	.32150	-0.81179	.51179
PR.13	Equal variances assumed	.009	.925	-0.100	29	.921	-.03636	.36451	-.78188	0.70915
	Equal variances not assumed			-0.102	22.080	.920	-.03636	.35659	-.77574	0.70301
PR.14	Equal variances assumed	.604	.443	.010	29	.992	.00455	.47111	-.95898	0.96807
	Equal variances not assumed			.009	18.387	.993	.00455	.49109	-1.02564	1.03473

Table 56: Independent T-Test for the Impact of BIM Risks on its Cost Reduction (Size of Organization Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
PR.1	Equal variances assumed	2.414	.131	-1.886	29	.069	-0.79348	.42064	-1.65379	0.06683
	Equal variances not assumed			-1.610	9.684	.139	-0.79348	.49277	-1.89630	0.30935
T.1	Equal variances assumed	.063	.803	-.871	29	.391	-.40217	.46186	-1.34678	0.54243
	Equal variances not assumed			-.851	11.766	.412	-.40217	.47269	-1.43434	0.62999
PL.1	Equal variances assumed	.069	.795	0.248	29	.806	.11957	.48272	-0.86770	1.10683
	Equal variances not assumed			0.249	12.381	.807	.11957	.47972	-0.92210	1.16123
PR.2	Equal variances assumed	0.054	.818	0.579	29	.567	.26630	.45956	-0.67361	1.20622
	Equal variances not assumed			0.539	10.868	.601	.26630	.49452	-0.82374	1.35635
PR.3	Equal variances assumed	.198	.660	0.634	29	.531	.26630	.41993	-.59255	1.12516
	Equal variances not assumed			0.594	11.001	.564	.26630	.44825	-.72028	1.25289
PR.4	Equal variances assumed	0.081	.778	-.961	29	.345	-.41304	.43000	-1.29248	0.46640
	Equal variances not assumed			-1.039	14.230	.316	-.41304	.39772	-1.26478	0.43869
PL.2	Equal variances assumed	2.956	.096	.064	29	.949	.02717	.42501	-0.84207	.89642
	Equal variances not assumed			.054	9.634	.958	.02717	.50003	-1.09274	1.14709
PR.5	Equal variances assumed	0.175	.678	.129	29	.898	.05435	.42004	-.80473	.91343
	Equal variances not assumed			.118	10.618	.908	.05435	.45922	-.96085	1.06955
T.2	Equal variances assumed	0.249	.621	0.196	29	.846	.09783	.49817	-.92104	1.11669
	Equal variances not assumed			0.189	11.507	.853	.09783	.51677	-1.03349	1.22914
PR.6	Equal variances assumed	2.180	.151	1.163	29	.254	.50543	.43442	-.38305	1.39391
	Equal variances not assumed			1.425	19.063	.170	.50543	.35459	-.23657	1.24744
PR.7	Equal variances assumed	.084	.775	-.371	29	.713	-.14130	.38094	-.92041	.63780
	Equal variances not assumed			-.344	10.847	.737	-.14130	.41045	-1.04626	.76365
PR.8	Equal variances assumed	.629	.434	.037	29	.971	.01630	.44019	-0.88399	.91660
	Equal variances not assumed			.041	14.856	.968	.01630	.39902	-0.83490	.86751
PR.9	Equal variances assumed	4.486	**.043**	-0.305	29	.762	-.12500	.40958	-.96268	0.71268
	Equal variances not assumed			-0.261	9.696	**.800**	-.12500	.47934	-1.19760	0.94760
PR.10	Equal variances assumed	.997	.326	-0.489	29	.629	-0.23370	.47815	-1.21162	0.74423
	Equal variances not assumed			-0.428	10.003	.678	-0.23370	.54600	-1.45022	0.98283
PR.11	Equal variances assumed	.026	.872	0.827	29	.415	.40761	.49272	-.60011	1.41533
	Equal variances not assumed			0.833	12.398	.421	.40761	.48929	-.65469	1.46990
PR.12	Equal variances assumed	4.270	**.048**	-1.435	29	.162	-.61957	.43190	-1.50290	.26377
	Equal variances not assumed			-1.175	9.230	**.269**	-.61957	.52711	-1.80746	.56833
PR.13	Equal variances assumed	.003	.958	-0.060	29	.952	-.02717	.45152	-.95064	0.89629
	Equal variances not assumed			-0.062	12.784	.952	-.02717	.44092	-.98137	0.92702
PR.14	Equal variances assumed	1.166	.289	.196	29	.846	.10326	.52595	-.97242	1.17894
	Equal variances not assumed			.221	15.467	.828	.10326	.46815	-.89195	1.09847

Table 57: Independent T-Test for the Impact of BIM Risks on its Time Reduction (Size of Organization Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
PR.1	Equal variances assumed	2.478	.126	1.068	29	.294	0.55435	.51903	-.50718	1.61588
	Equal variances not assumed			1.208	15.690	.245	0.55435	.45907	-.42040	1.52910
T.1	Equal variances assumed	2.272	.143	2.417	29	.022	1.02717	.42501	.15793	1.89642
	Equal variances not assumed			2.929	18.547	.009	1.02717	.35069	.29195	1.76240
PL.1	Equal variances assumed	.096	.758	1.013	29	.319	.45652	.45065	-0.46516	1.37820
	Equal variances not assumed			1.126	15.104	.278	.45652	.40542	-0.40710	1.32015
PR.2	Equal variances assumed	4.519	**.042**	-0.907	29	.372	-.36957	.40768	-1.20337	.46424
	Equal variances not assumed			-0.743	9.240	**.476**	-.36957	.49710	-1.48965	.75052
PR.3	Equal variances assumed	1.664	.207	0.941	29	.354	.34239	.36385	-.40177	1.08656
	Equal variances not assumed			0.794	9.548	.447	.34239	.43125	-.62470	1.30948
PR.4	Equal variances assumed	0.796	.380	.463	29	.647	.21739	.46932	-.74247	1.17725
	Equal variances not assumed			.484	13.269	.636	.21739	.44941	-.75151	1.18630
PL.2	Equal variances assumed	0.057	.813	-.713	29	.482	-.30978	.43471	-1.19886	.57929
	Equal variances not assumed			-.684	11.422	.508	-.30978	.45302	-1.30239	.68283
PR.5	Equal variances assumed	1.271	.269	.746	29	.461	.24457	.32769	-.42564	.91477
	Equal variances not assumed			.950	21.023	.353	.24457	.25750	-.29090	.78003
T.2	Equal variances assumed	1.727	.199	1.490	29	.147	.71739	.48154	-.26746	1.70225
	Equal variances not assumed			1.901	21.171	.071	.71739	.37736	-.06699	1.50177
PR.6	Equal variances assumed	3.929	.057	1.752	29	.090	.84239	.48078	-.14092	1.82570
	Equal variances not assumed			2.250	21.520	.035	.84239	.37439	.06494	1.61984
PR.7	Equal variances assumed	.094	.761	.177	29	.860	.05978	.33682	-.62908	.74865
	Equal variances not assumed			.165	10.835	.872	.05978	.36317	-.74103	.86059
PR.8	Equal variances assumed	.006	.940	-1.028	29	.313	-.44565	.43365	-1.33257	.44127
	Equal variances not assumed			-1.042	12.543	.317	-.44565	.42788	-1.37346	.48215
PR.9	Equal variances assumed	1.356	.254	0.930	29	.360	.41848	.44984	-.50155	1.33851
	Equal variances not assumed			1.159	19.900	.260	.41848	.36108	-.33495	1.17191
PR.10	Equal variances assumed	.227	.637	0.932	29	.359	0.48370	.51894	-.57765	1.54504
	Equal variances not assumed			0.845	10.480	.417	0.48370	.57257	-.78419	1.75158
PR.11	Equal variances assumed	.292	.593	1.703	29	.099	.73913	.43409	-.14868	1.62694
	Equal variances not assumed			1.691	12.093	.117	.73913	.43720	-.21265	1.69091
PR.12	Equal variances assumed	1.855	.184	.101	29	.920	.04891	.48314	-0.93922	1.03705
	Equal variances not assumed			.124	18.862	.903	.04891	.39601	-0.78036	.87818
PR.13	Equal variances assumed	3.511	.071	1.107	29	.277	.57065	.51552	-.48370	1.62500
	Equal variances not assumed			1.277	16.451	.219	.57065	.44675	-.37431	1.51561
PR.14	Equal variances assumed	3.612	.067	.265	29	.793	.14130	.53343	-.94968	1.23228
	Equal variances not assumed			.329	19.787	.745	.14130	.42912	-.75443	1.03704

Table 58: Independent T-Test for the Impact of BIM Risks on its Collaboration Improvement (Size of Organization Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference: Lower	Upper
PR.1	Equal variances assumed	0.074	.788	0.967	29	.341	0.37500	.38772	-.41797	1.16797
	Equal variances not assumed			1.117	16.489	.280	0.37500	.33567	-.33488	1.08488
T.1	Equal variances assumed	2.682	.112	1.219	29	.233	.57065	.46827	-.38708	1.52838
	Equal variances not assumed			1.464	18.132	.160	.57065	.38989	-.24805	1.38935
PL.1	Equal variances assumed	1.052	.314	0.393	29	.698	.20109	.51232	-0.84673	1.24890
	Equal variances not assumed			0.434	14.956	.670	.20109	.46298	-0.78598	1.18816
PR.2	Equal variances assumed	0.177	.677	-0.149	29	.883	-.07065	.47444	-1.04098	.89968
	Equal variances not assumed			-0.157	13.578	.877	-.07065	.44903	-1.03655	.89525
PR.3	Equal variances assumed	.231	.635	0.784	29	.439	.34239	.43645	-.55024	1.23502
	Equal variances not assumed			0.660	9.513	.525	.34239	.51891	-.82188	1.50667
PR.4	Equal variances assumed	4.306	.047	.913	29	.369	.48370	.53001	-.60030	1.56769
	Equal variances not assumed			1.069	17.050	.300	.48370	.45248	-.47075	1.43814
PL.2	Equal variances assumed	1.192	.284	-.132	29	.896	-.05978	.45431	-0.98895	.86939
	Equal variances not assumed			-.148	15.469	.884	-.05978	.40437	-0.91940	.79983
PR.5	Equal variances assumed	2.229	.146	.519	29	.607	.22826	.43944	-.67049	1.12701
	Equal variances not assumed			.655	20.568	.519	.22826	.34824	-.49688	.95340
T.2	Equal variances assumed	2.848	.102	0.894	29	.379	.42935	.48052	-.55343	1.41212
	Equal variances not assumed			1.087	18.734	.291	.42935	.39493	-.39804	1.25673
PR.6	Equal variances assumed	1.353	.254	1.048	29	.303	.54891	.52354	-.52184	1.61967
	Equal variances not assumed			1.175	15.376	.258	.54891	.46723	-.44484	1.54267
PR.7	Equal variances assumed	2.339	.137	-.056	29	.956	-.02174	.38670	-.81262	.76914
	Equal variances not assumed			-.047	9.559	.963	-.02174	.45790	-1.04843	1.00496
PR.8	Equal variances assumed	.465	.501	-.762	29	.452	-.34239	.44956	-1.26185	.57706
	Equal variances not assumed			-.812	13.816	.431	-.34239	.42182	-1.24823	.56345
PR.9	Equal variances assumed	.183	.672	0.149	29	.883	.07065	.47444	-.89968	1.04098
	Equal variances not assumed			0.157	13.578	.877	.07065	.44903	-.89525	1.03655
PR.10	Equal variances assumed	1.332	.258	-0.819	29	.419	-0.35870	.43771	-1.25391	0.53652
	Equal variances not assumed			-0.678	9.338	.514	-0.35870	.52874	-1.54822	0.83083
PR.11	Equal variances assumed	.407	.529	0.367	29	.716	.15761	.42974	-.72131	1.03652
	Equal variances not assumed			0.399	14.410	.696	.15761	.39512	-.68759	1.00281
PR.12	Equal variances assumed	0.197	.660	-.548	29	.588	-.20652	.37694	-0.97745	.56440
	Equal variances not assumed			-.641	16.979	.530	-.20652	.32236	-0.88671	.47366
PR.13	Equal variances assumed	1.818	.188	1.349	29	.188	.52174	.38670	-.26914	1.31262
	Equal variances not assumed			1.543	16.100	.142	.52174	.33822	-.19489	1.23837
PR.14	Equal variances assumed	1.826	.187	.530	29	.600	.27174	.51266	-.77677	1.32025
	Equal variances not assumed			.646	18.838	.526	.27174	.42042	-.60871	1.15219

Table 59: Independent T-Test for the Impact of BIM Risks on its Cost Reduction (Position Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PR.1	Equal variances assumed	0.332	.569	-2.038	29	.051	-0.79524	.39019	-1.59327	0.00279
	Equal variances not assumed			-1.992	16.818	.063	-0.79524	.39923	-1.63824	0.04777
T.1	Equal variances assumed	.139	.712	-1.203	29	.239	-.51429	.42740	-1.38841	0.35984
	Equal variances not assumed			-1.190	17.318	.250	-.51429	.43210	-1.42467	0.39610
PL.1	Equal variances assumed	2.257	.144	0.454	29	.653	.20476	.45072	-0.71707	1.12660
	Equal variances not assumed			0.532	26.349	.599	.20476	.38507	-0.58625	.99577
PR.2	Equal variances assumed	0.091	.765	0.077	29	.939	.03333	.43261	-0.85146	.91813
	Equal variances not assumed			0.076	17.111	.940	.03333	.43952	-0.89351	.96017
PR.3	Equal variances assumed	.918	.346	0.459	29	.650	.18095	.39436	-.62561	0.98751
	Equal variances not assumed			0.485	20.546	.633	.18095	.37295	-.59569	0.95759
PR.4	Equal variances assumed	2.963	.096	-.023	29	.982	-.00952	.40885	-.84571	0.82666
	Equal variances not assumed			-.027	25.213	.979	-.00952	.35648	-.74339	0.72434
PL.2	Equal variances assumed	0.024	.878	-.578	29	.568	-.22857	.39559	-1.03764	.58050
	Equal variances not assumed			-.577	17.723	.571	-.22857	.39624	-1.06198	.60483
PR.5	Equal variances assumed	0.060	.809	-.413	29	.683	-.16190	.39214	-.96393	.64012
	Equal variances not assumed			-.425	19.135	.676	-.16190	.38113	-.95924	.63543
T.2	Equal variances assumed	0.524	.475	0.071	29	.944	.03333	.46658	-.92093	0.98759
	Equal variances not assumed			0.076	21.213	.940	.03333	.43589	-.87260	0.93926
PR.6	Equal variances assumed	0.728	.401	0.356	29	.725	.14762	.41511	-.70138	0.99662
	Equal variances not assumed			0.371	19.840	.715	.14762	.39787	-.68275	0.97799
PR.7	Equal variances assumed	.008	.931	-2.004	29	.054	-.67143	.33497	-1.35652	.01366
	Equal variances not assumed			-2.000	17.694	.061	-.67143	.33574	-1.37767	.03481
PR.8	Equal variances assumed	3.141	.087	-.406	29	.688	-.16667	.41089	-1.00703	.67369
	Equal variances not assumed			-.485	27.382	.632	-.16667	.34388	-0.87179	.53846
PR.9	Equal variances assumed	3.723	.064	-1.908	29	.066	-.69048	.36196	-1.43077	0.04981
	Equal variances not assumed			-1.673	13.242	.118	-.69048	.41281	-1.58064	0.19968
PR.10	Equal variances assumed	2.758	.108	-2.763	29	.010	-1.10476	.39986	-1.92256	-0.28697
	Equal variances not assumed			-2.405	13.056	.032	-1.10476	.45932	-2.09663	-0.11290
PR.11	Equal variances assumed	.291	.594	-0.710	29	.483	-.32857	.46261	-1.27472	0.61758
	Equal variances not assumed			-0.685	16.281	.503	-.32857	.47977	-1.34422	0.68707
PR.12	Equal variances assumed	4.247	**.048**	-2.347	29	.026	-.90000	.38355	-1.68445	-.11555
	Equal variances not assumed			-2.113	13.976	**.053**	-.90000	.42594	-1.81371	.01371
PR.13	Equal variances assumed	.296	.591	-0.509	29	.614	-.21429	.42080	-1.07491	0.64634
	Equal variances not assumed			-0.541	20.775	.594	-.21429	.39627	-1.03892	0.61035
PR.14	Equal variances assumed	1.128	.297	-.145	29	.886	-.07143	.49246	-1.07862	0.93577
	Equal variances not assumed			-.158	22.101	.876	-.07143	.45288	-1.01040	0.86754

Table 60: Independent T-Test for the Impact of BIM Risks on its Time Reduction (Position Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference: Lower	Upper
PR.1	Equal variances assumed	4.834	.036	1.422	29	.166	0.68095	.47888	-.29848	1.66038
	Equal variances not assumed			1.614	24.613	.119	0.68095	.42188	-.18862	1.55052
T.1	Equal variances assumed	.113	.739	1.351	29	.187	.57143	.42295	-.29360	1.43646
	Equal variances not assumed			1.316	16.693	.206	.57143	.43409	-.34571	1.48857
PL.1	Equal variances assumed	1.447	.239	0.831	29	.413	.35238	.42421	-0.51523	1.21999
	Equal variances not assumed			1.006	27.977	.323	.35238	.35012	-0.36484	1.06960
PR.2	Equal variances assumed	5.118	.031	-1.920	29	.065	-.70000	.36450	-1.44548	.04548
	Equal variances not assumed			-1.709	13.639	.110	-.70000	.40961	-1.58071	.18071
PR.3	Equal variances assumed	.187	.668	0.994	29	.328	.33810	.34000	-.35728	1.03347
	Equal variances not assumed			0.931	15.223	.366	.33810	.36300	-.43464	1.11083
PR.4	Equal variances assumed	0.271	.607	-.130	29	.898	-.05714	.44080	-.95868	0.84439
	Equal variances not assumed			-.137	20.405	.893	-.05714	.41796	-.92789	0.81361
PL.2	Equal variances assumed	2.667	.113	-.560	29	.580	-.22857	.40825	-1.06354	.60640
	Equal variances not assumed			-.642	25.181	.527	-.22857	.35616	-0.96182	.50468
PR.5	Equal variances assumed	1.399	.246	.031	29	.976	.00952	.30966	-.62381	.64286
	Equal variances not assumed			.034	23.887	.973	.00952	.27619	-.56065	.57970
T.2	Equal variances assumed	0.000	.995	0.419	29	.679	.19524	.46627	-.75838	1.14886
	Equal variances not assumed			0.422	18.121	.678	.19524	.46293	-.77689	1.16736
PR.6	Equal variances assumed	2.090	.159	1.629	29	.114	.73810	.45298	-.18835	1.66454
	Equal variances not assumed			1.789	22.664	.087	.73810	.41253	-.11599	1.59218
PR.7	Equal variances assumed	.010	.922	-.378	29	.708	-.11905	.31467	-.76262	.52453
	Equal variances not assumed			-.371	16.937	.715	-.11905	.32103	-.79656	.55846
PR.8	Equal variances assumed	.205	.654	-1.811	29	.080	-.70952	.39168	-1.51060	.09155
	Equal variances not assumed			-1.953	21.612	.064	-.70952	.36331	-1.46377	.04472
PR.9	Equal variances assumed	.774	.386	0.823	29	.417	.34762	.42241	-.51630	1.21154
	Equal variances not assumed			0.885	21.493	.386	.34762	.39265	-.46780	1.16304
PR.10	Equal variances assumed	1.597	.216	0.251	29	.803	0.12381	.49244	-.88333	1.13095
	Equal variances not assumed			0.229	14.358	.822	0.12381	.53993	-1.03151	1.27913
PR.11	Equal variances assumed	.194	.663	0.872	29	.391	.36667	.42068	-.49372	1.22706
	Equal variances not assumed			0.887	18.593	.387	.36667	.41346	-.50001	1.23334
PR.12	Equal variances assumed	0.055	.816	-.454	29	.653	-.20476	.45072	-1.12660	.71707
	Equal variances not assumed			-.457	18.075	.653	-.20476	.44795	-1.14559	.73606
PR.13	Equal variances assumed	1.074	.309	1.064	29	.296	.51429	.48329	-.47416	1.50273
	Equal variances not assumed			1.121	20.339	.275	.51429	.45883	-.44179	1.47036
PR.14	Equal variances assumed	4.288	.047	1.068	29	.294	.52381	.49036	-.47910	1.52672
	Equal variances not assumed			1.227	25.289	.231	.52381	.42698	-.35507	1.40268

Table 61: Independent T-Test for the Impact of BIM Risks on its Collaboration Improvement (Position Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PR.1	Equal variances assumed	0.040	.844	-0.796	29	.432	-0.29048	.36476	-1.03650	0.45555
	Equal variances not assumed			-0.777	16.725	.448	-0.29048	.37407	-1.08070	0.49974
T.1	Equal variances assumed	.294	.592	.159	29	.875	.07143	.44922	-.84732	0.99018
	Equal variances not assumed			.166	19.746	.870	.07143	.43134	-.82907	0.97193
PL.1	Equal variances assumed	6.307	**.018**	0.228	29	.821	.10952	.48040	-0.87301	1.09205
	Equal variances not assumed			0.273	27.445	**.787**	.10952	.40150	-0.71366	.93271
PR.2	Equal variances assumed	0.614	.440	-1.290	29	.207	-.55714	.43205	-1.44079	.32650
	Equal variances not assumed			-1.402	22.073	.175	-.55714	.39753	-1.38140	.26712
PR.3	Equal variances assumed	.793	.381	0.463	29	.647	.19048	.41133	-.65079	1.03174
	Equal variances not assumed			0.493	20.969	.627	.19048	.38598	-.61228	0.99324
PR.4	Equal variances assumed	20.490	**.000**	1.472	29	.152	.71429	.48540	-.27846	1.70703
	Equal variances not assumed			1.875	28.998	**.071**	.71429	.38095	-.06485	1.49342
PL.2	Equal variances assumed	4.896	**.035**	-1.132	29	.267	-.47143	.41628	-1.32282	.37996
	Equal variances not assumed			-1.340	26.898	**.192**	-.47143	.35190	-1.19359	.25073
PR.5	Equal variances assumed	3.306	.079	.428	29	.672	.17619	.41195	-.66634	1.01872
	Equal variances not assumed			.519	28.049	.608	.17619	.33937	-.51892	.87130
T.2	Equal variances assumed	0.176	.678	-0.674	29	.506	-.30476	.45241	-1.23005	0.62053
	Equal variances not assumed			-0.706	20.048	.489	-.30476	.43189	-1.20554	0.59601
PR.6	Equal variances assumed	0.443	.511	0.392	29	.698	.19524	.49794	-.82317	1.21364
	Equal variances not assumed			0.408	19.747	.687	.19524	.47812	-.80291	1.19339
PR.7	Equal variances assumed	.018	.894	-.475	29	.638	-.17143	.36058	-.90891	.56605
	Equal variances not assumed			-.468	17.120	.646	-.17143	.36626	-.94377	.60091
PR.8	Equal variances assumed	6.983	**.013**	-.804	29	.428	-.33810	.42034	-1.19778	.52159
	Equal variances not assumed			-1.029	28.981	**.312**	-.33810	.32857	-1.01012	.33393
PR.9	Equal variances assumed	.031	.861	-0.075	29	.941	-.03333	.44422	-.94187	0.87521
	Equal variances not assumed			-0.078	19.955	.938	-.03333	.42482	-.91963	0.85296
PR.10	Equal variances assumed	.626	.435	-0.415	29	.681	-0.17143	.41321	-1.01654	0.67368
	Equal variances not assumed			-0.378	14.334	.711	-0.17143	.45341	-1.14177	0.79891
PR.11	Equal variances assumed	1.926	.176	-0.960	29	.345	-.38095	.39693	-1.19278	0.43087
	Equal variances not assumed			-1.073	23.714	.294	-.38095	.35507	-1.11426	0.35235
PR.12	Equal variances assumed	0.039	.844	-.857	29	.399	-.30000	.35025	-1.01635	.41635
	Equal variances not assumed			-.902	20.324	.378	-.30000	.33262	-0.99312	.39312
PR.13	Equal variances assumed	.418	.523	-0.051	29	.960	-.01905	.37314	-.78220	0.74411
	Equal variances not assumed			-0.055	21.332	.957	-.01905	.34785	-.74175	0.70365
PR.14	Equal variances assumed	1.494	.231	.158	29	.875	.07619	.48199	-.90959	1.06197
	Equal variances not assumed			.179	24.338	.860	.07619	.42661	-.80364	0.95602

Table 62: Independent T-Test for the Impact of BIM Risks on its Cost Reduction (Experience Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
PR.1	Equal variances assumed	3.365	.077	-2.464	29	.020	-0.87815	.35635	-1.60697	-0.14933
	Equal variances not assumed			-2.388	23.109	.026	-0.87815	.36775	-1.63871	-0.11760
T.1	Equal variances assumed	.135	.716	-.534	29	.598	-.21849	.40937	-1.05573	0.61876
	Equal variances not assumed			-.532	27.434	.599	-.21849	.41092	-1.06101	0.62404
PL.1	Equal variances assumed	.014	.907	1.174	29	.250	.48739	.41513	-0.36165	1.33644
	Equal variances not assumed			1.198	28.999	.241	.48739	.40679	-0.34459	1.31938
PR.2	Equal variances assumed	0.892	.353	0.165	29	.870	.06723	.40622	-0.76358	.89804
	Equal variances not assumed			0.169	28.999	.867	.06723	.39805	-0.74688	.88134
PR.3	Equal variances assumed	5.560	**.025**	-0.522	29	.605	-.19328	.37004	-.95010	0.56355
	Equal variances not assumed			-0.503	22.175	**.620**	-.19328	.38394	-.98915	0.60260
PR.4	Equal variances assumed	1.657	.208	-2.783	29	.009	-.94958	.34117	-1.64736	-0.25180
	Equal variances not assumed			-2.757	26.667	.010	-.94958	.34446	-1.65677	-0.24239
PL.2	Equal variances assumed	1.360	.253	-1.431	29	.163	-.51681	.36119	-1.25553	.22191
	Equal variances not assumed			-1.393	23.968	.176	-.51681	.37090	-1.28235	.24874
PR.5	Equal variances assumed	0.448	.509	.376	29	.709	.13866	.36854	-.61509	.89240
	Equal variances not assumed			.369	25.322	.715	.13866	.37538	-.63396	.91127
T.2	Equal variances assumed	0.791	.381	-0.442	29	.661	-.19328	.43684	-1.08672	0.70016
	Equal variances not assumed			-0.438	26.432	.665	-.19328	.44177	-1.10063	0.71407
PR.6	Equal variances assumed	0.173	.681	-0.672	29	.507	-.26050	.38777	-1.05359	0.53258
	Equal variances not assumed			-0.661	25.690	.514	-.26050	.39407	-1.07100	0.54999
PR.7	Equal variances assumed	.060	.808	-1.606	29	.119	-.51681	.32173	-1.17482	.14121
	Equal variances not assumed			-1.598	27.256	.122	-.51681	.32342	-1.18011	.14649
PR.8	Equal variances assumed	.865	.360	-.880	29	.386	-.33613	.38199	-1.11739	.44512
	Equal variances not assumed			-.910	28.453	.371	-.33613	.36957	-1.09262	.42035
PR.9	Equal variances assumed	2.665	.113	-1.725	29	.095	-.59244	.34352	-1.29501	0.11014
	Equal variances not assumed			-1.681	24.090	.106	-.59244	.35249	-1.31981	0.13493
PR.10	Equal variances assumed	4.384	**.045**	-2.638	29	.013	-1.00000	.37911	-1.77537	-0.22463
	Equal variances not assumed			-2.519	20.565	**.020**	-1.00000	.39704	-1.82676	-0.17324
PR.11	Equal variances assumed	.031	.862	-0.153	29	.879	-.06723	.43814	-.96331	0.82886
	Equal variances not assumed			-0.155	28.765	.878	-.06723	.43333	-.95381	0.81935
PR.12	Equal variances assumed	0.000	.996	-.989	29	.331	-.38235	.38653	-1.17290	.40819
	Equal variances not assumed			-.986	27.462	.333	-.38235	.38791	-1.17766	.41295
PR.13	Equal variances assumed	.117	.734	-1.012	29	.320	-.39496	.39020	-1.19301	0.40309
	Equal variances not assumed			-1.036	28.968	.309	-.39496	.38132	-1.17489	0.38497
PR.14	Equal variances assumed	.845	.365	-.761	29	.453	-.34874	.45820	-1.28586	0.58838
	Equal variances not assumed			-.781	28.900	.441	-.34874	.44667	-1.26241	0.56494

Table 63: Independent T-Test for the Impact of BIM Risks on its Time Reduction (Experience Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PR.1	Equal variances assumed	0.054	.818	-0.490	29	.628	-0.22689	.46334	-1.17453	0.72075
	Equal variances not assumed			-0.491	28.117	.627	-0.22689	.46222	-1.17353	0.71975
T.1	Equal variances assumed	.036	.851	.777	29	.443	.31513	.40540	-.51402	1.14427
	Equal variances not assumed			.778	27.898	.443	.31513	.40530	-.51523	1.14548
PL.1	Equal variances assumed	2.279	.142	0.566	29	.576	.22689	.40098	-0.59321	1.04699
	Equal variances not assumed			0.590	27.434	.560	.22689	.38434	-0.56112	1.01490
PR.2	Equal variances assumed	4.075	.053	-1.036	29	.309	-.36975	.35696	-1.09982	.36032
	Equal variances not assumed			-1.003	22.928	.326	-.36975	.36876	-1.13272	.39323
PR.3	Equal variances assumed	3.577	.069	-0.481	29	.634	-.15546	.32349	-.81707	0.50614
	Equal variances not assumed			-0.465	22.866	.646	-.15546	.33430	-.84724	0.53632
PR.4	Equal variances assumed	2.590	.118	-1.552	29	.132	-.61765	.39798	-1.43161	0.19632
	Equal variances not assumed			-1.520	24.939	.141	-.61765	.40633	-1.45460	0.21930
PL.2	Equal variances assumed	0.184	.671	-1.766	29	.088	-.64706	.36635	-1.39634	.10222
	Equal variances not assumed			-1.759	27.399	.090	-.64706	.36785	-1.40131	.10719
PR.5	Equal variances assumed	0.447	.509	1.045	29	.305	.29832	.28556	-.28572	.88235
	Equal variances not assumed			1.080	28.398	.289	.29832	.27609	-.26688	.86352
T.2	Equal variances assumed	1.867	.182	-0.163	29	.872	-.07143	.43910	-.96950	0.82664
	Equal variances not assumed			-0.160	25.536	.874	-.07143	.44667	-.99038	0.84752
PR.6	Equal variances assumed	0.377	.544	0.293	29	.771	.13025	.44389	-.77761	1.03811
	Equal variances not assumed			0.292	27.182	.773	.13025	.44647	-.78554	1.04604
PR.7	Equal variances assumed	.329	.571	-.057	29	.955	-.01681	.29630	-.62280	.58919
	Equal variances not assumed			-.058	28.896	.955	-.01681	.29218	-.61447	.58085
PR.8	Equal variances assumed	.242	.627	-.721	29	.477	-.27731	.38475	-1.06420	.50958
	Equal variances not assumed			-.736	28.996	.468	-.27731	.37676	-1.04787	.49325
PR.9	Equal variances assumed	1.928	.176	0.031	29	.975	.01261	.40138	-.80831	0.83352
	Equal variances not assumed			0.032	28.680	.974	.01261	.38954	-.78448	0.80969
PR.10	Equal variances assumed	1.549	.223	-0.630	29	.533	-0.28992	.45993	-1.23057	0.65074
	Equal variances not assumed			-0.620	25.496	.541	-0.28992	.46796	-1.25275	0.67292
PR.11	Equal variances assumed	1.452	.238	0.883	29	.385	.34874	.39503	-.45919	1.15667
	Equal variances not assumed			0.865	24.937	.395	.34874	.40332	-.48202	1.17950
PR.12	Equal variances assumed	0.886	.354	-.537	29	.596	-.22689	.42279	-1.09160	.63781
	Equal variances not assumed			-.551	28.881	.586	-.22689	.41194	-1.06955	.61577
PR.13	Equal variances assumed	.493	.488	-0.091	29	.928	-.04202	.46269	-.98832	0.90429
	Equal variances not assumed			-0.092	28.975	.927	-.04202	.45489	-.97240	0.88836
PR.14	Equal variances assumed	3.114	.088	.269	29	.790	.12605	.46901	-.83318	1.08528
	Equal variances not assumed			.279	27.851	.782	.12605	.45103	-.79807	1.05017

Table 64: Independent T-Test for the Impact of BIM Risks on its Collaboration Improvement (Experience Group)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
PR.1	Equal variances assumed	0.077	.783	-0.133	29	.895	-0.04622	.34625	-.75439	0.66195
	Equal variances not assumed			-0.135	28.576	.894	-0.04622	.34352	-.74925	0.65681
T.1	Equal variances assumed	.492	.488	-1.044	29	.305	-.43277	.41443	-1.28037	0.41483
	Equal variances not assumed			-1.060	28.927	.298	-.43277	.40827	-1.26788	0.40233
PL.1	Equal variances assumed	4.638	.040	0.828	29	.414	.36975	.44641	-0.54327	1.28277
	Equal variances not assumed			0.862	27.721	.396	.36975	.42884	-0.50908	1.24858
PR.2	Equal variances assumed	0.660	.423	0.475	29	.638	.19748	.41570	-0.65273	1.04768
	Equal variances not assumed			0.482	28.941	.633	.19748	.40933	-0.63977	1.03473
PR.3	Equal variances assumed	1.869	.182	-0.744	29	.463	-.28571	.38416	-1.07140	0.49997
	Equal variances not assumed			-0.726	24.260	.475	-.28571	.39380	-1.09802	0.52660
PR.4	Equal variances assumed	1.802	.190	-.338	29	.737	-.15966	.47174	-1.12447	0.80514
	Equal variances not assumed			-.348	28.765	.730	-.15966	.45848	-1.09770	0.77837
PL.2	Equal variances assumed	0.452	.507	-2.047	29	.050	-.76471	.37350	-1.52859	-.00082
	Equal variances not assumed			-2.074	28.844	.047	-.76471	.36879	-1.51914	-.01028
PR.5	Equal variances assumed	0.063	.803	.979	29	.336	.37395	.38191	-.40715	1.15505
	Equal variances not assumed			.968	26.451	.342	.37395	.38617	-.41918	1.16708
T.2	Equal variances assumed	0.004	.952	-0.702	29	.488	-.29832	.42468	-1.16690	0.57026
	Equal variances not assumed			-0.713	28.904	.482	-.29832	.41868	-1.15473	0.55809
PR.6	Equal variances assumed	1.261	.271	-1.300	29	.204	-.59244	.45589	-1.52483	0.33996
	Equal variances not assumed			-1.286	26.509	.210	-.59244	.46079	-1.53872	0.35384
PR.7	Equal variances assumed	.062	.805	.685	29	.499	.23109	.33731	-.45878	.92097
	Equal variances not assumed			.686	27.989	.498	.23109	.33693	-.45908	.92127
PR.8	Equal variances assumed	3.227	.083	-.929	29	.360	-.36555	.39340	-1.17015	.43905
	Equal variances not assumed			-.967	27.762	.342	-.36555	.37804	-1.14023	.40914
PR.9	Equal variances assumed	.030	.863	-0.794	29	.434	-.32773	.41285	-1.17211	0.51665
	Equal variances not assumed			-0.799	28.507	.431	-.32773	.40999	-1.16688	0.51142
PR.10	Equal variances assumed	.832	.369	-1.849	29	.075	-0.68067	.36820	-1.43373	0.07239
	Equal variances not assumed			-1.799	23.835	.085	-0.68067	.37839	-1.46192	0.10057
PR.11	Equal variances assumed	1.128	.297	-0.911	29	.370	-.34034	.37342	-1.10407	0.42339
	Equal variances not assumed			-0.930	29.000	.360	-.34034	.36607	-1.08904	0.40837
PR.12	Equal variances assumed	5.238	.030	.139	29	.891	.04622	.33303	-0.63490	.72734
	Equal variances not assumed			.146	25.747	.885	.04622	.31582	-0.60328	.69571
PR.13	Equal variances assumed	.180	.674	-0.975	29	.338	-.33613	.34492	-1.04157	0.36930
	Equal variances not assumed			-0.978	28.211	.336	-.33613	.34374	-1.04002	0.36775
PR.14	Equal variances assumed	2.885	.100	.093	29	.927	.04202	.45288	-.88422	0.96825
	Equal variances not assumed			.097	27.518	.924	.04202	.43435	-.84841	0.93244

Appendix D: *One-Way ANOVA Tests for the Impact of BIM Risks on its Advantages*

Table 65: One-Way ANOVA Test for the Impact of BIM Risks on its Cost Reduction (BIM Experience Group)

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
PR.1	Between Groups	2.108	2	1.054	.920	.410
	Within Groups	32.085	28	1.146		
	Total	34.194	30			
T.1	Between Groups	.156	2	.078	.058	.944
	Within Groups	37.521	28	1.340		
	Total	37.677	30			
PL.1	Between Groups	3.270	2	1.635	1.240	.305
	Within Groups	36.923	28	1.319		
	Total	40.194	30			
PR.2	Between Groups	.432	2	.216	.167	.847
	Within Groups	36.342	28	1.298		
	Total	36.774	30			
PR.3	Between Groups	.655	2	.327	.304	.740
	Within Groups	30.120	28	1.076		
	Total	30.774	30			
PR.4	Between Groups	1.728	2	.864	.777	.469
	Within Groups	31.111	28	1.111		
	Total	32.839	30			
PL.2	Between Groups	2.020	2	1.010	.973	.391
	Within Groups	29.077	28	1.038		
	Total	31.097	30			
PR.5	Between Groups	2.421	2	1.211	1.212	.313
	Within Groups	27.966	28	.999		
	Total	30.387	30			
T.2	Between Groups	1.099	2	.549	.369	.695
	Within Groups	41.675	28	1.488		
	Total	42.774	30			
PR.6	Between Groups	1.248	2	.624	.533	.592
	Within Groups	32.752	28	1.170		
	Total	34.000	30			
PR.7	Between Groups	1.404	2	.702	.830	.447
	Within Groups	23.692	28	.846		
	Total	25.097	30			
PR.8	Between Groups	.500	2	.250	.213	.809
	Within Groups	32.855	28	1.173		
	Total	33.355	30			
PR.9	Between Groups	.831	2	.415	.413	.665
	Within Groups	28.137	28	1.005		
	Total	28.968	30			
PR.10	Between Groups	5.558	2	2.779	2.280	.121
	Within Groups	34.120	28	1.219		
	Total	39.677	30			
PR.11	Between Groups	.655	2	.327	.218	.806
	Within Groups	42.120	28	1.504		
	Total	42.774	30			
PR.12	Between Groups	1.020	2	.510	.428	.656
	Within Groups	33.368	28	1.192		
	Total	34.387	30			
PR.13	Between Groups	1.404	2	.702	.584	.565
	Within Groups	33.692	28	1.203		
	Total	35.097	30			
PR.14	Between Groups	2.002	2	1.001	.614	.548
	Within Groups	45.675	28	1.631		
	Total	47.677	30			

Table 66: One-Way ANOVA Test for the Impact of BIM Risks on its Time Reduction (BIM Experience Group)

ANOVA						
		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
PR.1	Between Groups	0.535	2	0.268	.157	.855
	Within Groups	47.658	28	1.702		
	Total	48.194	30			
T.1	Between Groups	1.389	2	.695	.541	.588
	Within Groups	35.966	28	1.284		
	Total	37.355	30			
PL.1	Between Groups	1.270	2	0.635	0.509	.606
	Within Groups	34.923	28	1.247		
	Total	36.194	30			
PR.2	Between Groups	.223	2	.111	.107	.899
	Within Groups	29.197	28	1.043		
	Total	29.419	30			
PR.3	Between Groups	1.604	2	.802	1.026	.372
	Within Groups	21.880	28	0.781		
	Total	23.484	30			
PR.4	Between Groups	3.441	2	1.721	1.386	.267
	Within Groups	34.752	28	1.241		
	Total	38.194	30			
PL.2	Between Groups	1.575	2	0.788	.700	.505
	Within Groups	31.521	28	1.126		
	Total	33.097	30			
PR.5	Between Groups	1.728	2	0.864	1.413	.260
	Within Groups	17.111	28	.611		
	Total	18.839	30			
T.2	Between Groups	1.771	2	.886	.602	.555
	Within Groups	41.197	28	1.471		
	Total	42.968	30			
PR.6	Between Groups	0.632	2	.316	.204	.817
	Within Groups	43.368	28	1.549		
	Total	44.000	30			
PR.7	Between Groups	1.360	2	.680	1.047	.364
	Within Groups	18.188	28	.650		
	Total	19.548	30			
PR.8	Between Groups	.540	2	.270	.229	.797
	Within Groups	33.009	28	1.179		
	Total	33.548	30			
PR.9	Between Groups	.982	2	.491	.394	.678
	Within Groups	34.889	28	1.246		
	Total	35.871	30			
PR.10	Between Groups	0.067	2	0.033	0.020	.981
	Within Groups	47.675	28	1.703		
	Total	47.742	30			
PR.11	Between Groups	2.686	2	1.343	1.140	.334
	Within Groups	32.991	28	1.178		
	Total	35.677	30			
PR.12	Between Groups	1.117	2	.558	.400	.674
	Within Groups	39.077	28	1.396		
	Total	40.194	30			
PR.13	Between Groups	2.002	2	1.001	.614	.548
	Within Groups	45.675	28	1.631		
	Total	47.677	30			
PR.14	Between Groups	4.310	2	2.155	1.347	.276
	Within Groups	44.786	28	1.600		
	Total	49.097	30			

Table 67: One-Way ANOVA Test for the Impact of BIM Risks on its Collaboration Improvement (BIM Experience Group)

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
PR.1	Between Groups	2.402	2	1.201	1.383	.267
	Within Groups	24.308	28	0.868		
	Total	26.710	30			
T.1	Between Groups	.600	2	.300	.215	.808
	Within Groups	39.077	28	1.396		
	Total	39.677	30			
PL.1	Between Groups	3.727	2	1.864	1.252	.302
	Within Groups	41.692	28	1.489		
	Total	45.419	30			
PR.2	Between Groups	2.432	2	1.216	.937	.404
	Within Groups	36.342	28	1.298		
	Total	38.774	30			
PR.3	Between Groups	.715	2	.357	.305	.739
	Within Groups	32.769	28	1.170		
	Total	33.484	30			
PR.4	Between Groups	2.084	2	1.042	.612	.549
	Within Groups	47.658	28	1.702		
	Total	49.742	30			
PL.2	Between Groups	0.027	2	0.014	.011	.989
	Within Groups	35.521	28	1.269		
	Total	35.548	30			
PR.5	Between Groups	0.095	2	0.048	0.040	.961
	Within Groups	33.453	28	1.195		
	Total	33.548	30			
T.2	Between Groups	0.258	2	.129	.089	.915
	Within Groups	40.581	28	1.449		
	Total	40.839	30			
PR.6	Between Groups	2.199	2	1.099	.658	.526
	Within Groups	46.769	28	1.670		
	Total	48.968	30			
PR.7	Between Groups	0.443	2	.221	.245	.784
	Within Groups	25.299	28	.904		
	Total	25.742	30			
PR.8	Between Groups	.595	2	.297	.239	.789
	Within Groups	34.889	28	1.246		
	Total	35.484	30			
PR.9	Between Groups	5.082	2	2.541	2.112	.140
	Within Groups	33.692	28	1.203		
	Total	38.774	30			
PR.10	Between Groups	1.400	2	0.700	0.606	.553
	Within Groups	32.342	28	1.155		
	Total	33.742	30			
PR.11	Between Groups	1.132	2	.566	.515	.603
	Within Groups	30.803	28	1.100		
	Total	31.935	30			
PR.12	Between Groups	2.795	2	1.398	1.786	.186
	Within Groups	21.915	28	0.783		
	Total	24.710	30			
PR.13	Between Groups	1.440	2	.720	.778	.469
	Within Groups	25.915	28	0.926		
	Total	27.355	30			
PR.14	Between Groups	3.814	2	1.907	1.276	.295
	Within Groups	41.863	28	1.495		
	Total	45.677	30			

Appendix E: ***Survey Sample (Effects of BIM Risks on its Main Advantages)***

BIM stands for (Building Information Modeling), a new technology in construction projects which uses programs like (Revit, ArchiCAD....etc)

* 1. Select the nature of your organization

- ◯ Architecture
- ◯ Engineering Consultancy
- ◯ Contractor
- ◯ Private Client/ Developer
- ◯ Public Client/ Developer
- ◯ Software Supplier
- ◯ Other (please specify)

* 2. Indicate the size of your organization

- ◯ Less than 100 Employees
- ◯ 100 - 500 Employees
- ◯ 500 - 1000 Employees
- ◯ More than 1000 Employees

* 3. Indicate your role in your organization

- ◯ Draftsman
- ◯ Architect
- ◯ Engineer
- ◯ BIM Manager
- ◯ Design Manager
- ◯ Other (please specify)

* 4. Years of Experience

- ◯ Less than a year
- ◯ 1-2 years
- ◯ 2-5 years
- ◯ 5-8 years
- ◯ 8-10 years

* 5. Years of Experience in BIM

- ◯ None
- ◯ Less than a year
- ◯ 1-2 years
- ◯ 2-5 years
- ◯ 5-8 years
- ◯ 8-10 years
- ◯ More than 10 years

* 6. Does your organization use BIM?

- ◯ Yes
- ◯ No

7. If yes, how long has your organization been using BIM?

- ◯ Less than a year
- ◯ 1-2 years
- ◯ 2-5 years
- ◯ 5-8 years
- ◯ 8-10 years
- ◯ More than 10 years

8. If yes, how many projects have your organization delivered using BIM?

- ◯ Less than 20%
- ◯ 20%-40%
- ◯ 40%-60%
- ◯ 60%-80%
- ◯ 80%-100%

9. If no, when do you expect your organization will start using BIM?

- ◯ Less than a year
- ◯ 1-2 years
- ◯ 2-5 years
- ◯ More than 5 years
- ◯ Never

Three of BIM's ADVANTAGES are:

1- Reducing Project Cost

2- Reducing Project Time

3- Improving Team Collaboration

Do you think that these 3 advantages will be affected by the following BIM issues?

	BIM's Reduction of Project Costs	BIM's Reduction of Project Time	BIM's Increased Team Collaboration
Project team's lack of experience in BIM			
Incompatibility of BIM programs and loss of data			
BIM model copyrights are not defined			
Costs of training and recruitment			
Other project parties won't adapt BIM because of not knowing its benefits/preferring traditional method			
Absence of higher management support for BIM			
Lack of legal contracts specifically for BIM			

Do you think that these 3 advantages will be affected by the following BIM issues?

	BIM's Reduction of Project Cost	BIM's Reduction of Project Time	BIM's Increased Team Collaboration
Time spent for BIM training/learning			
Lack of electronic BIM standards (families, templates...etc)			
Lack of internal team organization and definition of responsibility of members' model input			
BIM's difficult implementation (It has to come in level by level)			
Cost of upgrading computers, technical support and software licenses			
Team members won't share information			
Project concepts are produced using CAD			
Time needed to start making the BIM model			
Recruited or trained BIM people leave their companies			
Unfamiliarity with BIM parametric concepts (parametric families)			
Gap in staff skills in 4D (scheduling) and 5D (cost estimating)			

Appendix F: ***Interview with Senior Products Manager in a British Multinational Engineering Consultancy***

Question 1:

In your opinion, what are the main challenges of BIM on the global market level and how can they be solved or prevented?

The main challenge essentially is the change part on BIM and keeping everyone sort of current so if you take for example the UK mandate which has had a major impact globally on the drive for BIM across Europe and the Middle East, it still hasn't taken traction in the UK as it should have, there is a number of reasons for that….partially it's the investment, it's overall getting the right resource and the right projects as well to be sort of mandated to drive BIM, but I certainly agree that the UK have probably done the most to drive BIM in the right direction "**That they are leading…**" They are certainly leading yeah and they continue to do so, I think the next iteration of it is about having very fixed milestones to achieve certain BIM uses for the whole industry and this will start to gather a bit more momentum, I think in conjunction with that there has been lots of collateral produced by the UK government and by the bodies that are supporting that mandate, there is continued momentum there, what we are seeing now is that instead of developing a lot of paper collateral, now they are really driving building digital tools and digital content "**Which is the main concept of BIM**" Absolutely yeah, I think it's been very much about developing the standards, another thing I think the standards created are really down to the working level, I think one of the other challenges we have experienced overall there seems to be a lot of theory within the global drive towards BIM and there hasn't been enough work at the coalface to really enable them or to equip them to drive the proper BIM delivery. There are a lot of engagements with the NBS (National Building Specification in UK) with key vendors such as Autodesk and Trimble to try to provide a lot more better tools, digital tools and digital content to really drive that BIM adoption "**For private companies?**" Well it's for the greater good of the industry, it's certainly for the UK market but a lot of that can be used and adapted for other regions.

Question 2:

How about the discrepancy between the demand for BIM between more developed and less developed countries?

Well that's always going to be challenging but nevertheless I think there will be a certain level of maturity required, so in more advanced economies such as the UK, Europe and the US there is sort of higher expectations about BIM but in places that we have seen like Africa there is a need to get the basics done, and that is to generate the design that is coordinated and check all the interfaces, that's the sort of fundamental level that you expect some of the basic BIM uses to achieve.

Question 3:

Do you think that the global initiatives to bridge this gap between the countries can actually help?

Well these things are never easy, right? If they were easy they would have been done before, so I think they do help but it's all a matter of maturity really and what they are able to achieve but you can see certainly in Africa in particular there is a lot of investments by Chinese companies and with that investment they need to do the design and construction in a really aggressive program and try to get it right the first time so I think that what has been done in more mature economies can be transferred to these emerging economies, maybe not all of it but at the same time it's always going to be adapted suitable to that particular sort of region.

Question 4:

Do you think that these movements should always be funded by the government or do you think that collaboration with the private sector can also help?

Well I think globally you can see two approaches, one is a global mandate which is what the UK have followed where the government has been the driver and the catalyst to change the industry for the better but you'll see in other countries where you get a bit more of a bottom-up approach where there is a bit more collaboration required, I think probably the example of Qatar where you've got government organizations that absorbed a lot of knowledge from the supply chain and certainly this is something that we need to do and it's been kind of driven from the bottom up.

Question 5:

Let's move to the next level, say on the contractual level or between the stakeholders in one project, what do you think are the implications of using BIM?

Yes, so what BIM really enables is collaboration first and foremost, so to align with that contracts need to be built around a collaborative nature, so I think this is where the pinpoints are because our working approaches are now changing but contractually they are still in their old style of the contractual relationships that we've got, so first and foremost contracts need to be adapted to suit this collaborative nature and how does that work with a win-win relationship all around, of course if someone loses out then that's not the essence of what the benefits of BIM should bring, so I see that contracts need to be reviewed and changed to align to the BIM methods, I think we've seen experiences with Public-Private Partnership projects in Asia where that collaborative nature has been adopted successfully and I think those sort of private-public initiatives are really beneficial for them so it's looking at that model and adapting it.

Question 6:

What is your view on partnering procurements among the stakeholders and their role in the implementation of BIM?

Yeah so the partnering approach is fundamental because of the collaborative nature that BIM brings so bringing contracts that have got partnering aspects can only benefit the implementation of BIM. "**Can that only be between the consultant and the contractor or it can be between any two parties within the stakeholders?**" No it must be of course from the owner level all the way to the sub-contractor on-site, it's good to be all inclusive otherwise it just fails, so yeah partnering must be across the whole spectrum of the supply chain.

Question 7:

Do you believe that this collaborative approach of BIM increases the risk sharing between the stakeholders?

Maybe in the short term because everyone is trying to understand the new dynamics here because there is a nature change in the industry but I think on the longer term these things will bottom out.

Question 8:

Now on the organizational level within the company itself, what do you think are the strategies to prevent the cultural change resistance and changing the whole system of the company?

Quite a lot of things that sort of have to happen concurrently, first and foremost you need top level endorsement of the BIM approach, secondly you need to have the investment behind that…"**I'm sorry by endorsements what do you mean exactly?**" So you need to have like the CEO right behind that, you need to mandate it, you need to have a high-level strategy signed off by the senior leadership team for that to really be in traction and support within the organization because it is really a change management exercise and a very significant way of changing the way that businesses are typically operated to a new way so that's kind of first and foremost, then you have to have a program behind that to deliver that change, it's not just about the technology change it's about a new process of working especially if you are a larger organization then you need to connect up multiple offices in order to make that change truly effective, so you can look at the Qatar mandate from a policy level, technology level, people level and a process level and having a plan around that to deliver.

Question 9:

So on one hand you've mentioned that large organizations face more difficulty because of their size in adapting to the new system, on the other hand it's been argued that the high initial costs can also make a challenge for small firms, so what do you think is better for each firm size and do you think that government funds can support small firms?

Well most definitely especially for small firms where margins are very small and there's a new technology piece, if that was available to them with a fund then that would certainly help the adoption but I think it's good to be aligned with having capable resource for that business to be able to support and be trained in the new approach as well so I would say that it's not only about the investment, it's about having the right resources available to train them in the adoption, so the approach also has to start small and then gradually build on that, it's not to go for big band deployment where you are truly disrupting the way the business operates, you need to do it gradually and mitigate all the sorts of risks as you implement BIM.

Question 10:

Do you believe that the incentives that certain organizations offer for their employees to be more willing to learn BIM are actually helpful?

It may well and I think that it depends on each of the organizations certainly with our organization we have a very strong culture of personal development and that's reviewed currently twice a year and variably we encourage through BIM as an objective and what does that mean to that particular person in their role in the organization, so a technician level would be to make sure that they are current with the technology tools and how to use those effectively and efficiently in project delivery, or maybe for a project manager how he needs to be educated in dealing with clients who are maybe immature in their understanding of BIM and also for project managers to know what is BIM and why it's important so for us; we have a program of a training course that helps those to understand consistently what is BIM to our organization.

Question 11:

On the project team level, let's say the coordination between different engineers, the ownership of different BIM models, how you would need more coordination because of the central model, the different approach of BIM design within the project team itself, what do you think are the main challenges within the team members?

The main challenge as I have experienced in our main projects has been communication, ensuring that everyone is working with the latest information that is available and ensuring that problems are resolved in a timely manner especially the sort of major problems because it may be in some major problems that there is multiple parties involved to resolve that. "**Any that are specific to BIM?**" Specific to BIM…not really, it's more of a design aspect point of view but I think what we realize is that in the context of BIM in particular, there is a lot more problems that surface because you are working in a 3D environment that we may have not traditionally seen, so it is about being able to kind of focus on that very much and be able to have a strategy to effectively resolve those issues and not let them drag on so that's been kind of our key challenge and particularly against the aggressive design and construction programs that we get, it's great having more advanced tools but we need to also have a strategy to say well, there might be one hundred clashes in a model but only twenty are major in nature and need to be resolved, so it's focusing that time and energy around those twenty and not everyone looking at the hundred, that's the focus of the change that we want to make, people get hung up over whether there's going to be a clash-free model but there is going to be cases where some of the clashes may actually be a sprinkler head or a light extruding through the ceiling "**Which is very minor**" Yeah absolutely, so it's understanding that and getting people to focus just on those key things.

Question 12:

Alright, so finally as for the added dimensions of BIM; 4D (Scheduling) and 5D (Cost Estimating), do you think they are still lacking as skills in project team members and that there is a gap?

Yeah currently there is, I think again we kind of see in certain larger organizations sort of silos of teams who are able to do fairly well, those who are just beginning to get exposed to it so it's about trying to share that knowledge in a consistent way but there is still sort of challenges around standards in some of these areas like what is the standard in the Middle East in particular, because we're somewhat of a cocktail of standards really, in some projects we have got to use American standards, some British standards "**I think Australian as well?**" Yeah, so there's a whole cocktail of standards and it would be really good to have a Middle East sort of defined standard and even if it's adopted by one of the key standard authorities and we follow that, so things can be executed firmly and effectively. "**Is this in terms of 4D and 5D modelling or is it BIM in general?**" I would say BIM in general actually, but this has a downstream effect on the 4D and 5D.

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