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INTEGRATION OF INNOVATION IN CONSTRUCTION MANAGEMENT

BY

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Abstract

Effective construction management is the best practice in the construction sector to achieve the project objectives and the vision for the company. The projects require high level of challenges to maintain the continuous improvement within the competitive global market. Keeping this in view, the concept of innovational practices in the construction sector is introduced as part of the construction management. This study applies the concept of innovation management in the construction industry by studying the major components of innovation process which include the major drivers to innovation, barriers and obstacles that prevent innovation, the enablers that motivate innovation, the practices of innovation, and the benefits of innovation related to project and firm level. This study depends on collecting data by constructing structured questionnaires with survey analysis. The survey consists of three parts; the first part is examining and surveying the organizations involved in the construction sector. The second part is exploring the most efficient and effective innovation components in order to approach the best innovation and construction management strategy. The third part is to identify the innovation outcome and the innovation models executed in the construction industry. The survey consists of 46 factors involved in innovation process and was distributed to different 121 participants, and the collected data was analyzed by relative importance index (RII) and then the analytical hierarchy process (AHP). The analysis results summarized that the most important input factor to initiate the innovation process is providing enough capital and funding the innovation process. Moreover, it is concluded that the major reason to initiate the innovation concept is the client requirement. The major obstacle to initiate the innovation process as per the data analysis is the shortage of financial support and resources to motivate and initiate the innovation practices. These are all external impact to innovation process. The internal impacts studied in this report consider

leadership as the most important factor that should be carefully applied in the innovation process. Finally, it is found that having new and modern methods of construction is the best innovation approach to achieve the organizational goals in order to increase the productivity and finish the projects earlier.

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Introduction

1.1 Introduction

In this chapter, a brief description about the background of construction industry in Qatar is presented along with unique construction challenges faced in Qatar which show the necessity of innovation integration in construction management. The research objectives of the project are also stated. Moreover, a clear understanding of the research approaches is indicated in the scope of work section to identify the dimensions and responsibilities. Finally, this chapter provides a brief explanation of the value and importance of this study and the project outline.

1.2 Background

Construction industry is one of the most sophisticated industries which require a huge effort of planning and studying due to involvement of many controlling factors. These Factors are considered as the challenges in achieving successful construction projects. Example of these factors are the country vision, financial stability, people and cultural understanding, logistics and projects location, transportation, resources availability, country stability and security, time constraint, and construction specifications and standards. Qatar is one of the developing countries that concentrate heavily on the construction industry to achieve its goals of FIFA World Cup 2022 and Qatar vision of 2030. Qatar faces many challenges to achieve its vision and to successfully meet the world's expectations of delivering the FIFA World Cup 2022 event. Qatar government requires completing the world class infrastructure system as promised to

FIFA. This involves achieving FIFA requirements and standards of having excellent transportation system, modern residential and hospitality facilities to support the predicted increase in population, and developing a world class sporting venues.

Qatar started executing major construction projects which are complex and require innovative ways of project management practices to overcome the challenges that cannot be handled by traditional project management practice. Examples of the major and complex projects in Qatar are Qatar railway Network and Metro projects, Hamad International Airport, New Doha Port Development, Lusail City Real Estate Development, Energy City, Msheireb Downtown Doha, Doha Festival City, Health Care facilities, and Stadiums.

There are four major dimensions to evaluate the project complexity level. These dimensions are the uniqueness, projects technology, scope complexity, and time to complete the project. Based on the above-mentioned dimensions, Construction projects in Qatar are considered very complex as most of the projects have new concept of execution in large scale. For example, construction of all football stadiums simultaneously will have large scale of construction with high technological features and services like applying system of weather proofing stadium. Moreover, most of the projects should finish all together in a challenged time frame. The urgency to finish before the starts of World Cup 2022 event will test the workability and efficiency of the planned projects.

1.3 Aims & Objectives:

This research project aims to analyze and study the current techniques of construction innovation including the factors that measure the performance of the innovation process in the construction industry.

The goal of this project can be summarized as follows:

- Study and analyze the innovation process components.
- Study and analyze the factors that affect the innovation performance (driver factors, enablers factors, barriers factors, input factors)
- Using AHP method, measure the performance and involvement in innovation for the construction organizations like (contractor, consultant, project management, and owner). The weight of organizations involvement is based on the average of total innovation factors ranking for each organization.
- Study and analyze the organization's view about the innovation factors (Rank each organization's point of view about the innovation factors)
- Study and analyze the innovation models used in the construction industry and their process components.
- Propose solutions to enhance the innovation process in construction industry

1.4 Scope of the Project

The scope of the project is to determine the innovation factors in construction industry analyze the level of importance and rank the innovation factors based on impact level to different organizations (contractor, project management, owner, supplier, and consultant). Moreover, the project highlights which organization in the construction industry should

focus more on the innovation process based on the market needs. The project analysis will be based on seven categories of the innovation process in the construction management, with a total of 46 factors in all categories.

Table 1.1 shows the innovation process categories with their factors. The research project analyzes the innovation factors with respect to the organizations involved in construction using Analytical Hierarchy Process (AHP) and using the Relative Importance Index (RII). The analysis involves evaluating the weights for the decision objectives which are the construction organizations in innovation process, then a pairwise comparison is conducted between the decision criteria which is made of innovation factors. The results will be the ranks of organizations in terms of their importance in the innovation process. These results also provide the rank of factors that have more impact level to innovation process.

Table 1.1 Innovation factors and categories

Innovation process			
No.	Categories	No.	Factors
1	Organizations benefits	1	Cost saving
		2	Time saving
		3	Quality improvement
		4	Technology improvement
		5	Construction safety improvement
		6	Market improvement
2	Innovation Drivers	7	Client requirement
		8	Competition level
		9	Project performance improvement
		10	Regulation and legislation
		11	Knowledge exchange
		12	Design trends
		13	Environment and sustainability
3	Innovation Barriers	14	Lack of financial resources

		15	Unsupportive organizational culture
		16	Temporary nature of projects
		17	Unavailability of materials
		18	Lack of experienced and qualified staff
		19	Lack of clear benefits
		20	Time constraint
4	Innovation Input factors	21	Capital
		22	Investment in R&D
		23	Internal knowledge management
		24	External knowledge management
		25	Consultancy
		26	Innovation team
5	Innovation Enablers	27	Effective cooperation
		28	Early contractor involvement
		29	Leadership
		30	Commitment
		31	Reward schemes
		32	Training policy
6	Models of Innovation	33	Modern methods of construction
		34	Project management tools
		35	Strategic Partnering
		36	Supply chain partnership
		37	Energy efficiency/ sustainability
		38	Building Information Modeling (BIM)
		39	Advanced materials
		40	Lean construction
		41	Automation
		42	Marketing
7	Innovation Output	43	Shorter project duration
		44	Increased productivity
		45	Improved technical and managerial capability
		46	Enhanced design trends

1.5 Importance of the Research Project

The construction projects are rigid in nature and the existing construction methods not flexible due to low involvement of innovation in the construction projects. Moreover, a lot of previous

studies considered only limited dimensions of innovation process in construction as there are limited research and development studies. This study reflects the innovation practices as the real demand of complex construction projects.

Construction projects nowadays are very complex due to new concepts of design, larger scale projects, and critical time limitation with high levels of quality specifications. Dealing with such complexity is not possible with the traditional view of construction. However, this research project studies the necessity of involvement of innovation in of construction projects with the help of AHP models.

1.6 Outline of the Report

The project report consists of six chapters, describing the research objective, overview of construction industry, overview of previous studies for similar research objective, importance of the project, analysis methodology, and finally the analysis results and conclusion. A summary of the above-mentioned chapters is presented as below;

- **Chapter 1 (Introduction):** This chapter provides a brief introduction of project content, background and overview of the project idea. Project objectives, scope of work, importance of the project, and outline are all covered in this chapter.
- **Chapter 2 (Research methodology):** This chapter explains the research methodology, and the process of data collection and data analysis.
- **Chapter 3 (Literature review):** In this chapter, several topics are discussed based on previous studies; these topics are related to the innovation factors and related to innovation in construction management. The innovation factors like process components, drivers of innovation, barriers of innovation, input factors to innovation, enablers to

innovation, and the innovation model in construction industry, are all explained in this chapter.

- **Chapter 4 (Data Demographic):** This chapter provides explanation on the process of data collection, the survey output values with graphs, charts, and tables.
- **Chapter 5 (Research analysis and Discussion):** Evaluation of the results collected and summarized in Chapter 4 is discussed using AHP method. Detailed explanation is provided in this chapter about the AHP method used in this project. The application of AHP method is explained in order to evaluate the weight of construction organizations, ranking of innovation factors for each construction organization, and final computations for the overall inn**o**vation factors ranking values.
- **Chapter 6 (Conclusion and Recommendation):** In this chapter, the project objectives achievement is discussed based on the analysis values, and conclusion is constructed with recommendation.

Chapter 2

Research Objectives and methodology

2.1 Introduction

In this chapter, the research objectives, methodology, and analysis techniques are discussed.

2.2 Objectives

The objectives of the research project are:

- Study the impact of innovation process to construction organizations.
- Determine the rankings in terms of importance of construction organizations in implementing the innovation practices at construction projects, using AHP analysis method.
- Analyze the impact level of innovation factors to the innovation process.
- Analyze the relationship between the innovation factors and the models of innovation in construction industry.

2.3 Research methodology

2.3.1 Introduction

In this section, the strategy and procedure of handling the research in the project is described. The research project was started with stating the project objectives and indicating the scope of

work. Then, a thorough literature view about the factors that control the project objectives was carried out. Figure 2.1 summarizes the research methodology steps.

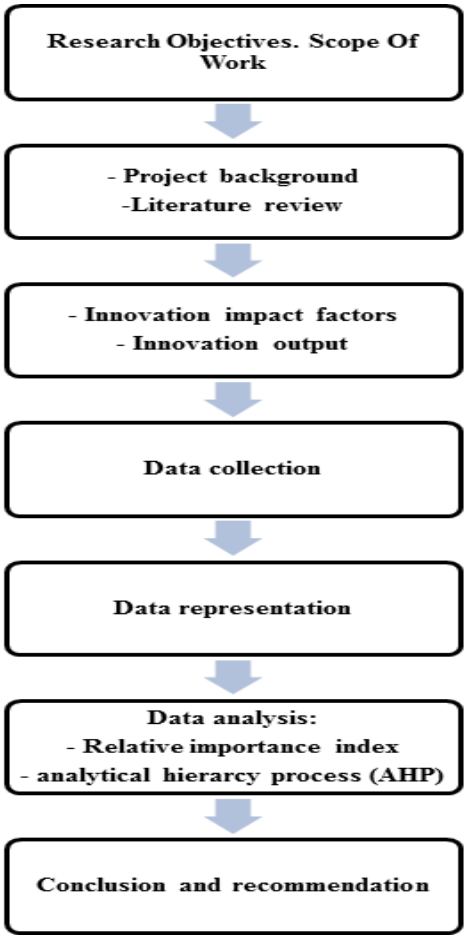

Figure 2. 1 Research methodology

2.3.2 Literature review

Literature review was performed to determine the innovation dimensions and the components that control the innovation process in construction industries. Moreover, literature review was also performed to study the innovation components factors. Literature review indicated that the innovation components are innovation drivers, enablers, barriers, input factors, and the innovation process output to construction organizations. Each component consists of different factors that have impact on the innovation components. Finally, literature review was performed to define the models of innovation process in construction organizations and the application of those models.

2.3.3 Data description

A survey was constructed for data collection and data analysis to investigate the involvement of construction organizations (contractor, consultant, owner, project management, and supplier) in the innovation process and to analyze the ranking of the impact level of different factors of innovation components in construction projects. There are 46 factors which were distributed in 7 innovation categories. Appendix A shows the survey questions that were distributed to 121 respondents. The survey was distributed online through website (surveymonkey.com) to different construction organizations. The social media pages for professional engineering societies were also used to distribute it among the respondents.

2.3.4 Data analysis

In this part, the collected data from the structured survey is analyzed for ranking the innovation factors. One of the project objectives is to find the most efficient innovation factors and the most

involved construction organizations in the innovation process. The best ranking method found during research and review of the previous studies is using AHP method which stands for analytical hierarchy process. This involves scoring the different factors of innovation process and making a pair wise comparison to test each factor's correlation to the other factors in the same group or category of innovation factors. The analysis method also depends on studying each construction organization. At the end, all factors related to innovation process for different construction organizations are correlated with each other to obtain overall rankings of innovation factors with respect to the involvement of each construction organization in innovation process.

Chapter 3

Literature review

3.1 Introduction

In this chapter, the factors for innovation and existing models in the construction industry are reviewed and explained by studying the previous academic literature related to innovation components and innovation in construction management. It includes definitions and explanations for the innovation components. The components of innovation which are considered here are driver's factors, barriers factors, input factors, enabler's factors, and the innovation output factors to different construction organizations.

3.2 Innovation in construction management

Innovation management is a management approach that integrates the necessary activities with respects to factors that affect the innovation process to efficiently implement an idea for product or process which will increase the ability of organization to compete. (Pellicer, Yepes, Correa, Alarcon, 2014)

In construction management, the innovation term can be defined as the successful introduction of new technologies or procedures into industry. The scope of innovation in construction industry is wide and can be executed to everything related to construction like new building products, materials and systems to construction technologies, and equipment and business operations. (Goodland, Lindberg, Paul, 2015)

There are different ways that innovations can arise in the construction management, which OECD summarize it into four different categories:

1. Product innovation: is related to goods or services that are new or significantly improved in purpose of achieving the pre-established needs or objectives. To apply such type of innovation in construction sector, a well-established knowledge about methods of improvement in technical specifications, components and materials, and incorporated software that enhance the communication between varieties of stakeholders is required. This type of innovation can lead either into a new product or service with new concept or improvement of existing knowledge or technologies to meet the pre-specified objective.
2. Process innovation: is the implementation of new method, technology, techniques, and equipment to improve the delivery method in purpose to increase the efficiency, and therefore, increase the resources utilization. The objective of process innovation is to decrease the cost of operation, decrease the wastage time, time saving, and increase the quality by setting up the acceptable tolerance.
3. Marketing innovation: is the implementation of new technique or marketing method involving significant changes in product design, product pricing, and product promotion or pricing technique. Marketing innovation are more involved in addressing the customer needs and highlight more in the way of delivery or communication between the service provider and the customers or the end users.

4. Organizational innovation: is the implementation of a new organizational method in the firm's business practices, workplace organization or external relations. Organizational innovation main objective is to increase the level of performance in a firm or organization

by reducing the cost of administration and transaction, information flow cost, improve the productivity to achieve the organizational satisfaction, and having access to the external marketing requirement and knowledge.

The four methods of innovation which are product, process, marketing, and organizational innovation can be commonly used in the construction industry due to the level of complexity of most of the construction projects and construction organizations. Complexity in construction sector is a result of having multiple stakeholders. These stakeholders start from the authorities and government that control the regulations and permits moving on to the sophisticated client requirements and ending up with the contractor who consists of other multiple stakeholders, the top management level, the medium management level, and the operation level stakeholders. Other factors of complexity in the construction sector are the external competition, market instability and challenges such as tight timelines to achieve completion for international events in the country.

Product innovation in construction sector is essential especially in the construction quality control and quality assurance (QA/QC) Departments. These sections work essentially on improving the material characteristics to improve the performance of material or product to solve and avoid major problems. A lot of examples can be raised on the product innovation in construction; one of them is the waterproofing product material that is applied beneath the reinforced concrete foundation. The innovation part in this example started when the engineers were not able to answer the question of how to guarantee the integrity and effectiveness of waterproofing membrane continuity without weak joints, punctured or leaked points that allow the underground water to penetrate the concrete structure after shutting down the dewatering system. The product innovation was to think of practical and simple solution that will be

applicable and executable in construction projects. The product innovation to ensure the quality of waterproofing membrane joints was to install a thin network wires like plastic wire below the waterproofing membrane. The proposed material has characteristic property to react with water and produce a small fire spark to indicate the location of water leak to repair and treat it.

Process innovation in construction sector is mainly related to the performance of the project to save the completion time duration, to reduce the resources allocation, and to work without environmental or conditional interference and conflicts. One of the examples showing the performance innovation is the development of bridge maker equipment which is used in assembling precast concrete decks automatically. The machine is automated to hold the concrete deck and installs it in the specified connection joints. The advantages of bridge maker are significant time savings, working without breakdown of the roads services, and reduction in use of formwork equipment.

Marketing innovation in construction sector is not involved in the construction implementation period; it is mainly involved in the procurement stage of the project, during the tendering stage. One of the common examples is employing ERP systems to provide communication platform between multiple stakeholders and establishing database of the contractors and subcontractors for the client in order to request for bidding. ERP system is commonly used in most of the construction organizations, for accounting, financial, human resources, contract, procurement and purchasing departments. This serves the purpose of organizational innovation as well as provides flexible communication and information flow between the organization disciplines. This also increases the ability of an organization to gain external knowledge by interfacing their organizational ERP with external organizations (suppliers, contractors, clients…etc.)

3.3 Innovation process components

Keeping in view the above discussion, it is established that construction environment is complex in nature due to different factors influencing the construction projects. Construction organizations have levels of innovation performance applied to their projects and their organizational activities. Measuring innovation is crucial in order to determine innovation performance of firms. It is a complicated process since there are no specific dimensions to control the innovation performance.

Traditionally, innovation is measured in terms of input and output. For example, the input factors to innovation previously were limited to research and development performance with output in terms of patent or trademark applications. (Ozorhon, 2013) However, innovation was not really effective because of not considering some important dimensions related to the construction industries which obstruct the innovation performance. These dimensions together with the input and output dimensions are shown in the figure below. Figure 3.1 presents the proposed innovation framework, which models innovation at the project level based on several components including the drivers, inputs, barriers, enablers, innovation models, and organizational benefits.

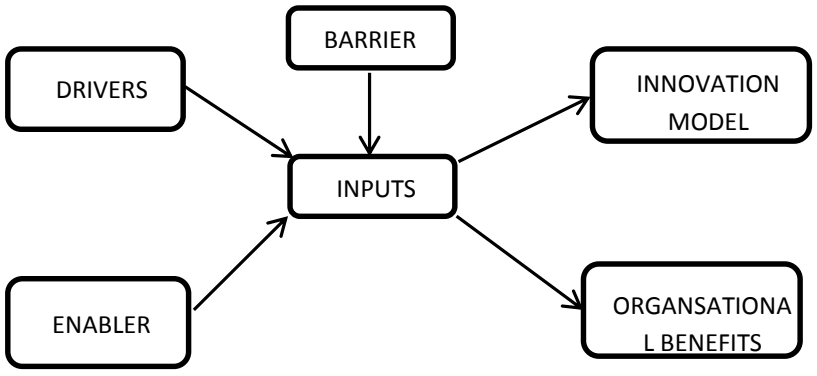

Figure 3. 1 Innovation framework

3.3.1 Drivers of innovation

Drivers of the development, design and realization of innovations in construction are explored under headings like ``innovation leaders" and ``innovation champions". (Bossink 2004)

Drivers of innovation are the reasons of making investment in innovation. Innovation itself is a project to execute and should have all projects phases and requirements. Drivers of innovation are the requirements dimensions for the innovation. The common drivers' factors in the construction industry are: Client requirements, competition level, project performance improvement, knowledge exchange, regulations and legislation, corporate responsibilities, design trends, and environment and sustainability.

1. Client requirements are considered as significant and common factor of drivers of innovation in the construction industry. It is an important factor to initiate the innovation process because it a major project requirement that lead the project participants to develop strategies to fulfill the client requirement. The clients also have the ability to foster innovation by expanding the interest for high standards and specification of work, and they worked as a leader in raising new concepts for a supportive work environment. (Ozorhon, Oral, Demirkesen 2013)

2. Competition level: Innovation is the main motivation factor to generate competition among organizations in the construction industry. Innovation related to increase the competition level is mainly enhancing the project performance. (Ozorhon, Oral, Demirkesen 2013)

3. Project performance improvement is one of the major driver factors that improves the performance by improving the project efficiency in terms of time, quality, cost, and client demand satisfaction. (Goodrum and Haas 2000; Ozorhon 2013)

4. Knowledge exchange: Knowledge exchange is one driver factor that is mainly related to stimulation of research, creation of knowledge network, programs promoting collaboration, broad view of risk, integrated and informal R&D function, effective information gathering, training of workers on site, and lateral communication structure. (Bossink, 2004)

5. Regulations and legislations: Regulations involving performance standards have a considerable effect on stimulating and fostering innovations through exerting pressure on construction companies (Reichstein et al. 2008).

6. Corporate responsibility: Corporate social responsibility (CSR) assumes a basic part in accomplishing higher customer fulfillment and enhancing corporate picture of organizations. Green (2008) states that: “CSR is mostly seen as a source for sustainability”. Borger and Kruglianskas (2006) stated that there is a strong relationship between the concept or the role of a CSR strategy and an effective environmental and innovative performance.

7. Design trends: for the complex projects which involve high level of technology or a totally new concept, the innovation should be considered from the design stage to meet the objectives. In order to achieve the design requirements, the innovation concept should be driven to combine technical capabilities, market demands, and opportunities. There is an increasing pressure on designers to develop more-innovative and more-competitive designs (Steele and Murray 2004). Clients anticipate that designers will utilize high levels of incorporated

technology and to make more-complex outlines that acquire a new generation of understanding the development innovation. (Goodrum and Haas 2000; Ozorhon 2013)

8. Environment and sustainability: Environmental innovation comprises of the utilization of sustainable production equipment, strategies, methods, items, and item delivery systems. The construction industry has recently worked on decreasing the environmental impact. Mostly, the environmental consideration is studied and involved in construction industry by measuring and establishing the uncertainty risk management. In this manner, construction of sustainable structures has a significant impact on the development of innovative solutions. (Goodrum and Haas 2000; Ozorhon 2013)

3.3.2 Barriers of innovation

Barriers are the obstacles and the challenges in the innovation process that may cause failure in investing in innovation. In this study, there are seven factors raised and identified as the innovation barriers, which are: lack of financial resources, unsupportive organizational culture, temporary nature of projects, unavailability of materials, lack of experienced and qualified staff, lack of clear benefits, and time constraints. These factors are explained as below;

1. Lack of financial resources: Financial resources are the most significant and critical resources in initiating and developing the innovation process in construction industry. Lack of financial resources is major obstacle and barrier to not only to develop the innovation process but it is also a barrier in the establishment of any construction organization in general.

2. Unsupportive organizational culture: some construction industries have an unwilling attitude towards changing the traditional way of construction and its modes of operation. Most of

the construction organizations are afraid to apply innovation because they do not have the any guarantee over the outcome of innovation. Furthermore, the risk of high cost handling the continuous innovation improvement is a barrier. Because of this, the construction industry has been widely criticized in terms of its weakness in absorbing new management practices and technologies. Therefore, unsupportive organizational cultures are considered one of the barriers to develop innovation practice in construction industry. (Goodrum and Haas 2000; Ozorhon 2013)

3. Temporary nature of projects: construction projects are normally executed by operational staff which is a separate team than innovation team of the organization. The construction teams normally operate the projects on a short-term basis which cause problems in the project delivery outcome. Similarly, unstable temporary construction projects make the innovation development difficult to transfer.

4. Unavailability of materials: Innovation development sometimes requires advanced materials as a requirement to achieve the innovation process deliverables. Advance materials may not be available in the local market and may require ordering the material internationally which will be time consuming. Therefore, unavailability of materials is considered one of the innovation process barriers.

5. Lack of experienced and qualified staff: Innovation process requires staff with external and internal knowledge of the construction based on which the innovation process can groom. Human resources department in construction organizations should take care about the staff technical and technological qualification. Lack of staff qualification and experience will lead to

major failure in innovation process development. Therefore, lack of experience is one of the barriers to innovation process development. (Ozorhon, 2013)

6. Lack of clear benefits: Innovation concept is commonly applied to the operation and production services which can integrate automation and robot technology for assembling and packing products. Construction industry is considered one of the oldest businesses which is established on traditional methods of construction and has no innovation practices once your construction projects at the end are statics and can be applied by the traditional ways. Based on this concept, the profit margins are normally lower in the construction industry and hence, the benefits should be clearly defined in construction profits with all related dimensions that need in investment. Therefore, construction managers may experience difficulties in ensuring the return on investment of the innovation.

7. Time constraints: Construction organizations experience difficulties in procuring the projects within the time and budget constraints. These constraints may obstruct the initiation of new concepts and testing new products or systems. Hardier. (2010) indicated that the time required for testing and developing a technical innovation is a barrier for innovation in small-and-medium-sized enterprises (SMEs).

3.3.3 Input factors to innovation

Inputs to innovation process are the most significant component and form the core of the innovation model. Input factors represent all resources needed to initiate and implement the innovation process which are mainly related human, financial, and organizational resources that all together are utilized to implement innovation. The input factors that will be covered in this

report are: 1) capital, 2) Investment in R&D, 3) Internal knowledge resources, 4) External knowledge resources, 5) Consultancy, 6) Innovation team. These are explained as given below;

1. Capital: Construction projects are complex in nature which requires large capital investment. Similarly, the innovation process requires large financial resources to support the process implementation. Innovation process consists of planning, purchasing new material, adopting technology, and programming and all of these steps need financial support.
2. Investment in R&D: research and development department is not commonly used in the construction industries as involvement of innovation in the construction sector is very low. However, in order to integrate the internal and external knowledge in innovation practice, investment on R&D is required as input factor to innovation process.
3. Internal knowledge resources: are the resources that are related to the experience gained from problems on previous projects and from the previous organizational practices. Moreover, internal knowledge resources are concerned about the role of facilitating the internal coordination between the organization members, and feedback for generating ideas.
4. External knowledge resources: construction projects consist of multiple numbers of parties such as suppliers, designers, engineers, contractors, subcontractors, clients and end users. Implementation of innovation requires sharing knowledge with all project parties in order to successfully achieve the innovation.
5. Consultancy: it is related to coordinate the client requirements with the innovation requirements. Consultants provide working relationship with technology suppliers, review the technical specifications to absorb and incorporate new technologies, and

establish strategic engineering methodologies that fulfill the client innovation requirements.

6. Innovation team: the innovation team is the heart of innovation process that will plan, execute, and monitor all stages of innovation process. The innovation team is not only involved in planning the requirements of innovation or who executes the process but is also involved in the R&D department

3.3.4 Enablers to innovation

Enablers include those factors that motivate the innovation process in the construction industry. Enabler's factors are important in order to study the strength of an organization in the construction industry by measuring the rate of having available activities that facilitate the innovation performance. The enabler's factors in this paper can be summarized into seven factors which are: cooperation, early contractor involvement, leadership, commitment, knowledge management, reward schemes, and training policy.

1. Cooperation: Successful innovation requires effective cooperation, coordination, and integration among contractors, sub-contractors, suppliers, architects, engineers, and clients in construction projects. Collaboration leads to a more integrated and well-coordinated environment during the innovation process in the construction industry, and innovation is difficult to be achieved in isolated environment, this is mainly because of involvement of innovation in a complex project which consist of multiple parties and stakeholders. Holmen Et Al (2005) found that most of the technological innovation practices executed in projects were as a result of a well cooperation executed as enabler of construction innovation.

2. Early contractor involvement: Early contractor involvement is one way to develop cooperative work environment between project parties which may lead to generate innovation to develop an efficient and value-adding solutions.

3. Leadership: Leadership is an important factor to motivate the innovation team to plan, and perform with innovation process. Leadership is considered as one of the main enablers of innovation in the construction industry. Previous studies have shown that leadership plays a critical role in shaping the project spirit (Aronson et al. 2013). Project managers are often represented as the leaders for the innovation team with the role of attracting the team members to follow procedures and provide attention for innovation.

4. Commitment: Construction organizations in construction projects have different obligations to follow, such as obey to the contract agreement terms, achieve the projects specifications, execute the scope of work, risk assessment, and other different commitments. Therefore, implementing the innovation process should be followed as organizational commitment to achieve the organizational objective. By this concept, commitment to perform with innovation is one of the essential way of motivate the team to achieve the innovation practice, and hence it is considered an important enabler's factor.

5. Knowledge management: Knowledge management is recognized as a database for generating and implementing innovation process performance. Project managers for the innovation should work on the mechanism and tools that foster knowledge sharing within a group in order to facilitate innovation. Effective knowledge is not limited only in exploring the right ideas into the project, but also ensuring that the ideas are well coordinated and communicated between the project team and concerned project parties (Ozorhon,2013). Therefore, knowledge management

strategies and approach need innovative efforts which make the knowledge area as one of the enabler's factors that help in innovation implementation.

6. Reward schemes: Successful innovation performance can be obtained by applying the reward system in the construction organizations. It involves recognition of innovators and innovation promotion in the companies. The innovation team personnel who take part in the successful innovation achievement related to the organizational innovation objectives must be rewarded. The outcome of applying reward system to innovation team is to increase the competition in working performance between the teams. Therefore, reward schemes are considered one of the motivation and enabler way to implement innovation process in the construction industry.

7. Training policy: Innovation team should have high level of experience in strategies and the procedures to implement the innovation process. Innovation process is mainly considered in solving present problem or enhancing the present performance by finding new alternatives or improved solutions. Ability to deal with these changes and new concept exploration require the team members to be well trained which can be achieved by training courses or on-site trainings. Training is essential in the diffusion of innovation among project personnel which should be mainly handled by the human resources department in the construction organization. Therefore, training is essential to enable the innovation process in the construction industry.

3.4 Innovation models in construction industry

- Modern methods of construction

A construction process that can encompass the use of composite new and traditional materials and components often with extensive factory produced sub-assembly sections and components. This may be in combination with accelerated on-site assembly methods and often to the

exclusion of many of the construction industry traditional trades. The process includes new buildings and retrofitting, repair and extension of existing buildings. Some of the perceived benefits of modern methods of construction are:

- Improved quality control of components produced under factory controlled conditions.
- Services (e.g. electrics, plumbing) can be pre-planned and either fully or partly pre-installed for final connection on site.
- Faster construction times on site.
- Fewer workers required on site and for shorter periods.

o Project management tools

Project management tools are most commonly used in construction industry to increase the probability of having successful construction project. The common five practices tools in project management are: strategic management, internal innovative working environment, external innovative working environment, stakeholder management, and project management. The innovation model can be achieved in the construction projects by applying the five tools in project management. There are different methods to apply the project management tools, examples of these methods are: SMART objectives, formulating strategies, SWOT analysis, and implementing the ten knowledge areas of project management. (Ghaben 2015)

o Strategic Partnering

A formal alliance between two commercial enterprises, usually formalized by one or more business contracts but falls short of forming a legal partnership or, agency, or corporate affiliate relationship. One common strategic partnership involves one company providing engineering, manufacturing or product development services, partnering with a smaller, entrepreneurial firm

or inventor to develop a specialized new product. Typically, the larger firm supplies capital, and the necessary product development, marketing, manufacturing, and distribution capabilities, while the smaller firm supplies specialized technical or creative expertise.

- Supply chain partnership

A supply chain partnership can be defined as an approach with an attitude or management ethos, (towards selected suppliers) of openness, effective communication, close collaboration and co-operation, trust, honesty, transparency, sharing and mutual benefit.

- Energy efficiency/ sustainability

One of the innovation practices executed in the construction industry is to achieve the goal of confirming the energy efficiency by establishing ideas, techniques, and standards to reduce the usage of energy with the same effective functionality. One example in the construction industry are the green buildings, which involve innovation in the services design like recycling the used water, reducing the electricity distribution to building and defining alternatives like saving the electricity usage of A/C units by applying cold chilled water system. Moreover, innovation can also be applied by finding alternatives materials that are environmental friendly. These materials in construction are mostly used for building insulation, like sound and thermal insulation.

- Building Information Modeling (BIM)

Building information modeling (BIM) is a process involving the generation and management of digital representations of physical and functional characteristics of places. Building information models (BIMs) are files which can be exchanged or networked to support decision-making about a place. Current BIM software is used by individuals, businesses and government agencies, which plan, design, construct, operate and maintain diverse physical infrastructures, such as water, wastewater, electricity, gas, refuse and communication utilities, roads, bridges and ports,

houses, apartments, schools and shops. Building information modeling (BIM) is commonly used in construction industry in the planning and execution phase. It is important in planning phase to understand the scale of construction project work with integrating all construction disciplines together. It is important technique in construction execution also, as it is a well method for coordinating between civil, architectural, mechanical, electrical, and plumbing works in the construction execution planning phase.

- Advanced materials

Using advanced materials in construction industry is one of the most important approaches to innovation process. This is mainly related to innovation by suppliers who continuously study the internal and external knowledge of different materials characteristics that can be used as alternative to the old and traditional material used before. The benefits of innovation approach in using advanced materials in construction are mainly related to repairing and renovation work, and using alterative light weight, flexible, and easy to use materials with same efficiency to save time and resources. For example, using light weight block instead of using the normal cement hollow block in construction, light weight block is bigger in size and lighter in weight which helps the designers to consider fewer loads to the structure and hence reduce the steel reinforcement required. Another example is using basalt fiber in the concrete mix as a replacement of installing steel reinforcement bars in slab on grade which is very efficient in controlling the cracks in concrete due to temperature change.

- Lean construction

Lean construction is a combination of operational research and practical development in design and construction with an adaption of lean manufacturing principles and practices to the end-to-

end design and construction process. Unlike manufacturing, construction is a project based-production process. Lean construction is concerned with the alignment and holistic pursuit of concurrent and continuous improvements in all dimensions of the built and natural environment: design, construction, activation, maintenance, salvaging, and recycling (Abdelhamid 2007, Abdelhamid et al. 2008).

- Automation

Automation or automatic control is the use of various control systems for operating equipment such as machinery, processes in factories, boilers and heat treating ovens, switching on telephone networks, steering and stabilization of ships, aircraft and other applications with minimal or reduced human intervention. Some construction processes have been completely automated. The biggest benefit of automation is that it saves labor; however, it is also used to save energy and materials and to improve quality, accuracy and precision. The best example of automation in construction industry is executed in Japan; automated cranes control system which is used to lift precast concrete members and steel structure to construct high rise building only by construction material assembling. Another example is the tunneling work which needs high automation level drilling, dismantling, and installing the precast tunnel.

3.5 Analytical Hierarchy Process (AHP)

3.5.1 Definition and history

The analytic hierarchy process (AHP) is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology. It was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then. It has particular application in group decision making, and is used around the world in a wide variety of decision situations, in fields such as government, business, industry, healthcare, shipbuilding and education. Rather than prescribing a "correct" decision, the AHP helps decision makers find one that best suits their goal and their understanding of the problem. It provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions.

AHP is a method for ranking several decision alternatives and selecting the best one when the decision maker has multiple objectives, or criteria, on which to base the decision. The decision maker will select the alternatives that best meet the decision criteria. AHP is a process for developing a numerical score to rank each decision alternatives based on how well the alternative meets the decision maker’s criteria. The AHP provides such a framework that enables us to make effective decisions on complex issues by simplifying and expediting our natural decision-making processes. Basically the AHP is a method of (1) breaking down a complex, unstructured situation into its component parts; (2) arranging these parts, or variables into a hierarchic order; (3) assigning numerical values to subjective judgments on the relative importance of each variable; and (4) synthesizing the judgments to determine which variables have the highest priority and should be acted upon to influence the outcome of the situation.

3.5.2 Major Steps of AHP

Prior starting AHP implementation, major assumption should be considered in the analysis study, that all decision criterions or variables are independent to each other.

1) To develop a graphical representation of the problem in terms of the overall goal, the criteria, and the decision alternatives.

2) To specify judgments about the relative importance of each criterion in terms of its contribution to the achievement of the overall goal.

3) To indicate a preference or priority for each decision alternative in terms of how it contributes to each criterion.

4) Given the information on relative importance and preferences, a mathematical process is used to synthesize the information (including consistency checking) and provide a priority ranking of all alternatives in terms of their overall preference

3.5.3 Advantages of the AHP

- The AHP enables people to refine their definition of a problem and to improve their judgment and understanding through repetition
- The AHP does not insist on consensus but synthesizes a representative outcome from diverse judgments
- The AHP takes into consideration the relative priorities of factors in a system and enables people to select the best alternative based on their goals
- The AHP leads to an overall estimate of the desirability of each alternative

- The AHP provides a single, easily understood, flexible model for a wide range of unstructured problems
- The AHP integrates deductive and systems approaches in solving complex problems
- The AHP can deal with the interdependence of elements in a system and does not insist on linear thinking.
- The AHP reflects the natural tendency of the mind to sort elements of a system into different levels and to group like elements in each level
- The AHP provides a scale for measuring intangibles and a method for establishing priorities
- The AHP tracks the logical consistency of judgments used in determining priorities

3.5.4 AHP implementation in project analysis

AHP implementation in the analysis of the project is based on prioritizing the innovation factors by collecting data about the importance level for each factor in the innovation process in the construction industry.

AHP analysis method is used to test the factors of innovation process which are considered as the decision criteria. There are 46 decision criteria related to the innovation process in the construction industry, all those decision criteria are tested and evaluated to find out the importance level of these factors with respect to their relative weight to different organizations (contractors, owners, project management, suppliers, and consultants). Ranking all factors will provide result in terms of which factors should be involved more and should be considered more in the construction innovation process. The objective or the decision of AHP in this project is to answer which organization is of

more concern in the construction innovation process and the rank of construction organizations who are more involved in innovation process. After data collection of the importance level for each factor, the study ranked the 46 innovation factors in seven categories with the help of AHP.

The next step is the scoring of different factors in each innovation category based on the importance level to obtain the ranking of factors collected based on the data collected through questionnaire survey. The scoring is done via pair wise comparison for different innovation factors to each other, from 1-9 score frame. Table 3.1 shows the scoring criteria and meaning associated to the decision criteria innovation factors. The next step after scoring the factors and pair wise comparison is the normalization process. Normalizing the matrix has been done by totaling the numbers in each column. Then each entry in the column is divided by the column sum to yield its normalized score. The sum of each column should yield 1.

Table 2.1 scoring table for AHP method

SCALE	Degree of preference
1	Equal Importance
3	Moderate importance of one factor over another
5	Strong or essential importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Values for inverse comparison

The last step involved synthesizing the results to determine the best alternative, and obtaining the final result. The output of AHP is the set of priorities of the alternatives. Each decision alternatives graded in terms of how well it satisfies the criterion according to the following formula:

$$Si = \sum gij \times Wj$$

Where:

W_j = a weight between 0 and 1assigned to criterion j; 1.00 Important, 0 Unimportant; sum of total weighs equals one.

g_{ij} = a grade between 0 and 100 indicating how well alternative i satisfies criteria j; 100 indicates high satisfaction, 0 low satisfaction

Chapter 4

Data Demographics

4.1 Introduction

In this chapter, data collected from different countries mostly from Qatar and other Middle Eastern, and North African countries is presented. Figure 4.1 summarizes the location of survey participants' location: 70.8% from Qatar, 25.8% from Middle East and North Africa, 2.5% from North America, 0.8% from Europe. The data collected from professionals with different years of experience (most of participant have well experience in the construction industry) is shown in Figure 4.2: 16.5% have less than 5 years' experience, 23.1% have experience of 5-10 years in construction industry, 30.6% are those who have experience between 10-15 years, and 29.8% of the participants have experience more than 15 years.

The survey was responded by different disciplines in construction industry; most of them are from construction, technical design and engineering departments. In this part, data collected from the different organizations involved in the construction is presented along with 46 innovation factors that are categorized in 7 categories (innovation process impact factors, innovation driver's factors, innovation barrier/s factors, innovation input factors, innovation enabler's factors, innovation type factors, and innovation output factors). The charts resulting from 121 survey participants are presented in this chapter.

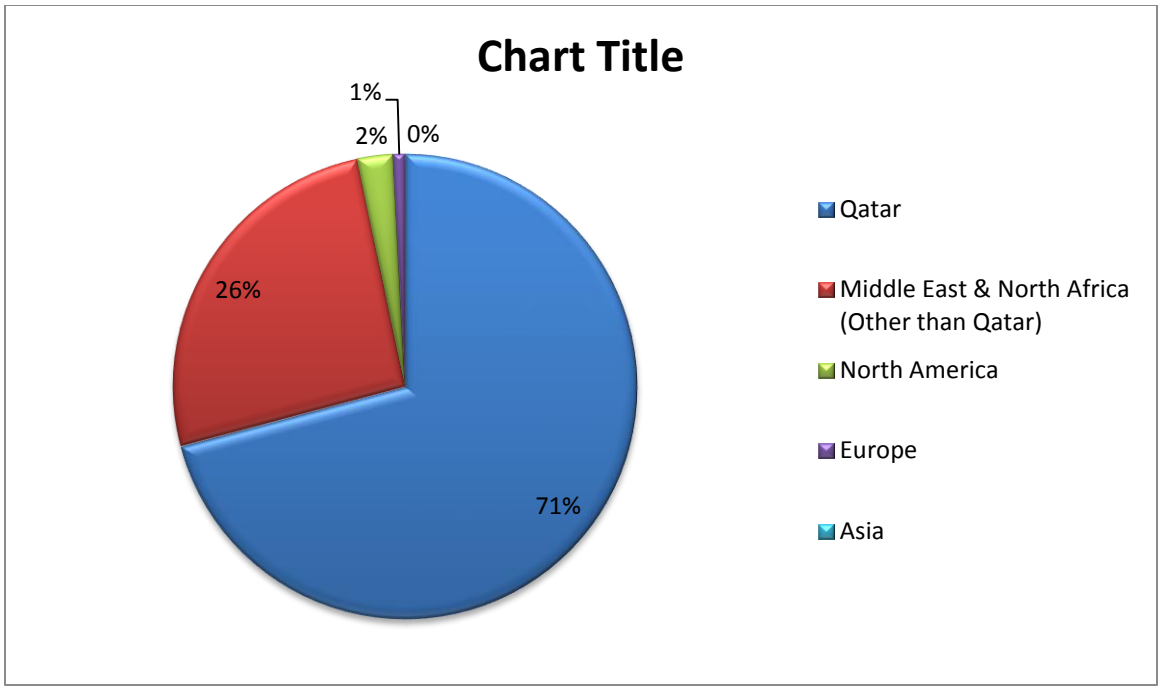

Figure4. 1 Country distribution of survey responses

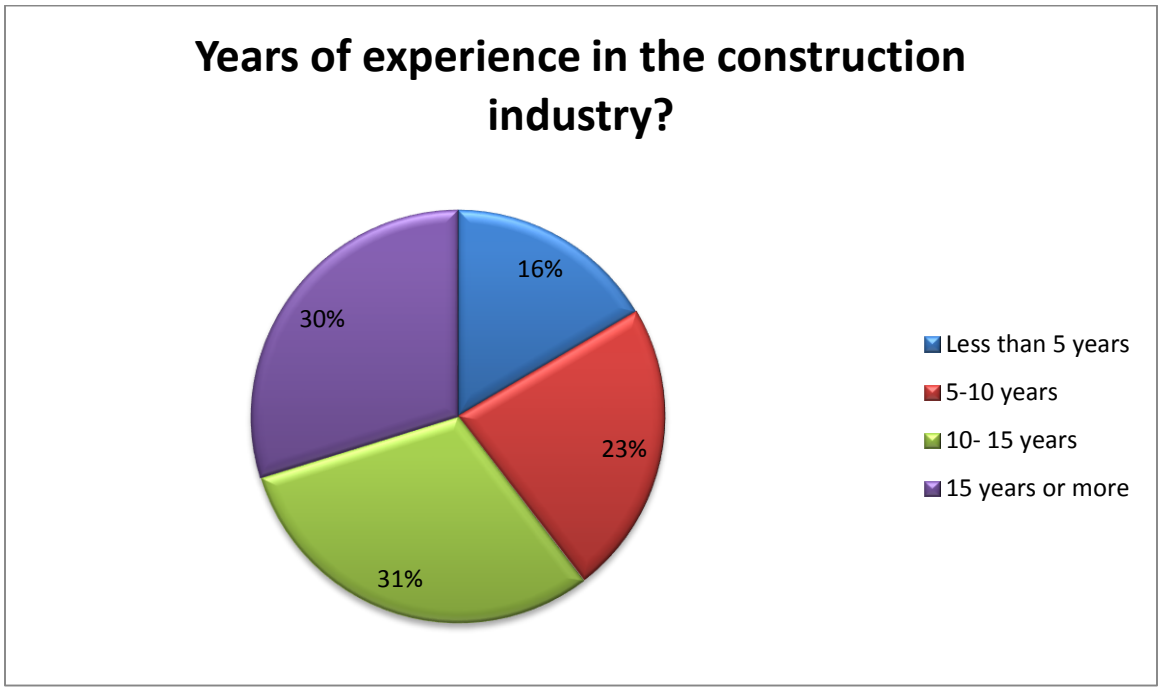

Figure4. 2 years of experience of respondents

4.2 Construction organizations

The study of innovation process in construction was based on the involvement of different organizations in the innovation practices. The difficulty faced in data collection is that most of the construction organizations are not involved into the innovation process due to the rigid nature of construction. The construction organizations involved in this survey are contractors, consultants, owner's representatives, suppliers, and project management consultants. Figure 4.3 shows the involvement level of different organizations in the constructed survey, which represents 43.8% contractors, 12.4% consultants, 14% owner representatives, 17.4% project management, and 12.4% are suppliers.

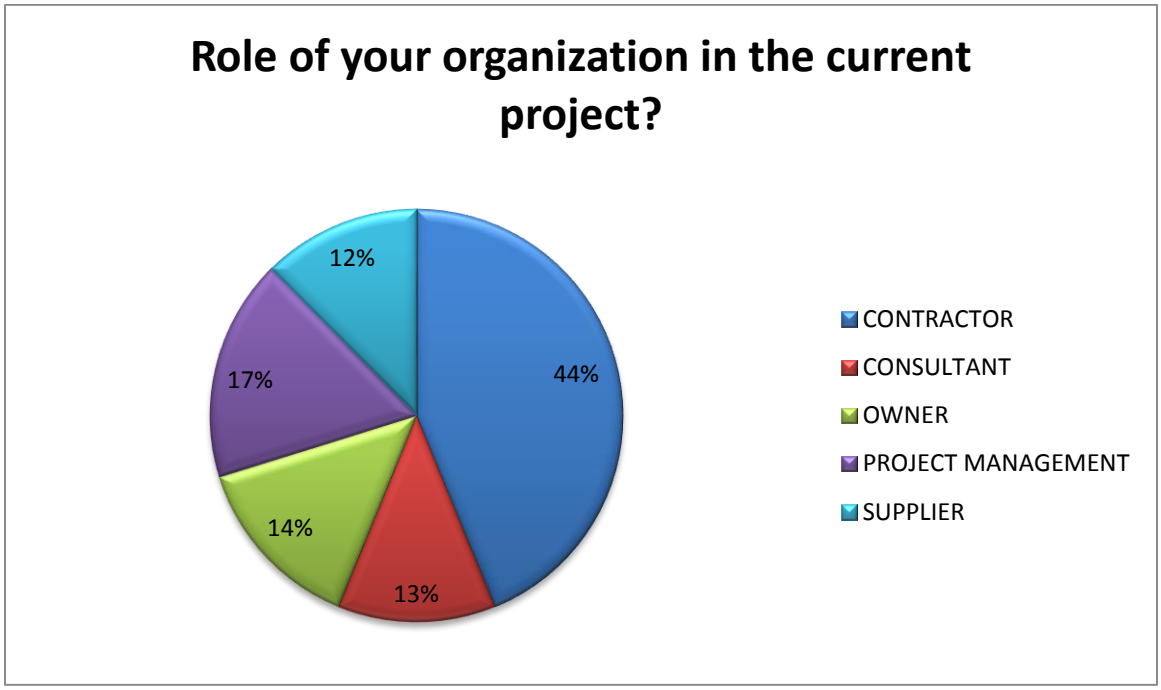

Figure 4. 3 involvement of construction organizations to survey

4.3 Innovation components

The innovation factors impact level are analyzed by using Likert scale questions with large scale between 1 to 9 due to multiple number of factors analyzed which require large scale to have accurate results and avoid score duplications. As mentioned in the above sections, the components that build up the innovation process are summarized in seven categories and each category was tested and analyzed based on the participant's opinion about its impact and involvement level in the innovation process. The first category was the different impact factors to innovation approach, which is composed of 6 different factors. Table 4.1 summarizes the respondents and the average ratings summarized from the survey questionnaire. It is noticed that time saving factor has the highest impact level on innovation process. However, all results shown are close to each other with total rating average of 6.48. Figure 4.4 summarizes how close the results are to each other.

Table 3.1 Innovation impact factors survey results

Please indicate the impact level of each listed factor on innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; (1 – lowest/minor impact 9 – highest impact) Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Cost saving	4	2	2	3	12	17	31	23	27	6.88	121
2) Time saving	2	3	4	1	8	17	21	21	44	7.25	121
3) Quality improvement	1	2	4	10	11	10	28	26	29	6.92	121
4) Technology improvement	1	7	7	13	24	24	24	15	6	5.74	121
5) Construction safety improvement	2	1	5	13	17	24	27	18	14	6.27	121
6) Market improvement	5	6	4	18	17	20	22	17	12	5.82	121

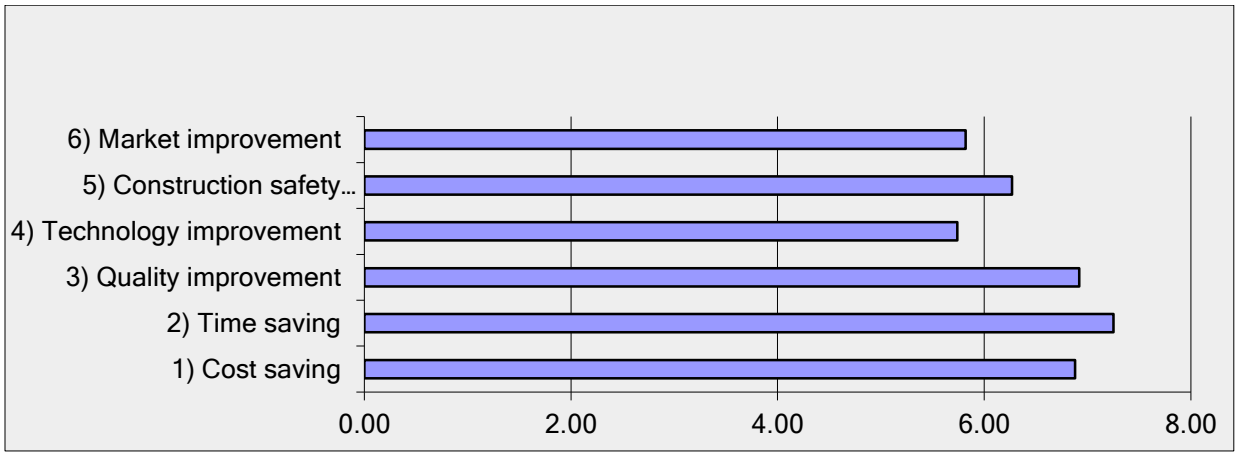

Figure4. 4 chart of innovation impact factors survey results

Another component of innovation process is the innovation driver, which consists of 7 different factors assigned to the main innovation driver factors. These are the client requirements with average rating of 7.58 out of 9, competition level with 6.26, project performance improvement with 7.02, regulation and legislation with 5.75, knowledge exchange with 5.59, design trends with 6.5, and environment and sustainability with 6.24 weights out of 9. These results are described and shown in table 4.2 and figure 4.5.

Table 4.2 1 Overall driver's factors survey results

Please indicate the impact level of each listed driver factor on innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; (1 - lowest/minor impact 9 - highest impact) Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Client requirement	0	1	3	3	9	8	14	21	47	7.59	106
2) Competition level	0	2	3	11	17	20	30	15	8	6.26	106
3) Project performance improvement	0	1	5	5	11	12	19	30	23	7.02	106
4) Regulation and legislation	1	9	8	21	9	10	21	12	15	5.75	106
5) Knowledge exchange	2	4	9	19	18	19	14	11	10	5.59	106
6) Design trends	1	1	2	6	15	24	26	24	7	6.50	106
7) Environment and sustainability	2	3	4	10	12	21	28	15	11	6.24	106

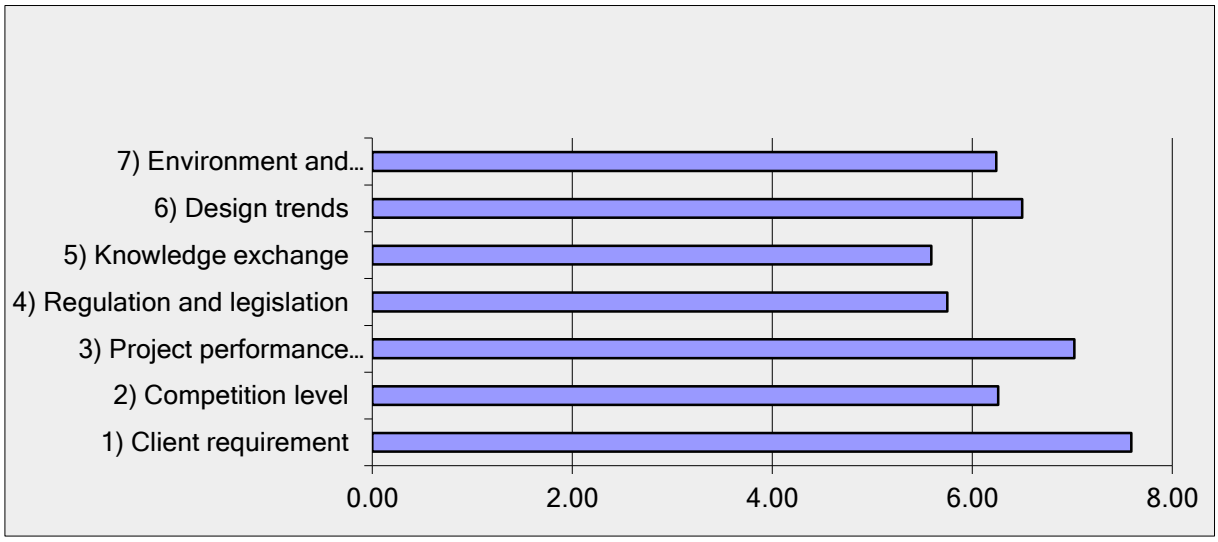

Figure4. 5 Driver's factors overall survey results

Another component of innovation process is the innovation barrier. This component consists of 7 different factors assigned to the main innovation barrier factors. These are the lack of financial resources with average rating of 7.58 out of 9, unsupportive organizational culture with 6.39,

temporary nature of projects with 5.72, unavailability of materials with 5.79, lack of experienced and qualified staff with 6.74, lack of clear benefits with 5.86, and time constraint with 6.41 weight out of 9. The results are described and shown in table 4.3 and figure 4.6.

Table 4.3 1 Overall barrier factors survey results

Please indicate the impact level of each listed barrier factor to implement innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; (1 – lowest/minor impact 9 – highest impact) Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Lack of financial resources	2	2	2	3	7	7	13	18	52	7.58	106
2) Unsupportive organizational culture	0	2	6	9	14	21	22	19	13	6.39	106
3) Temporary nature of projects	2	5	4	11	24	24	19	12	5	5.72	106
4) Unavailability of materials	5	7	5	11	17	20	13	12	16	5.79	106
5) Lack of experienced and qualified staff	1	0	4	11	13	15	16	24	22	6.74	106
6) Lack of clear benefits	3	4	8	15	13	16	18	22	7	5.86	106
7) Time constraint	0	2	6	12	15	15	19	22	15	6.41	106

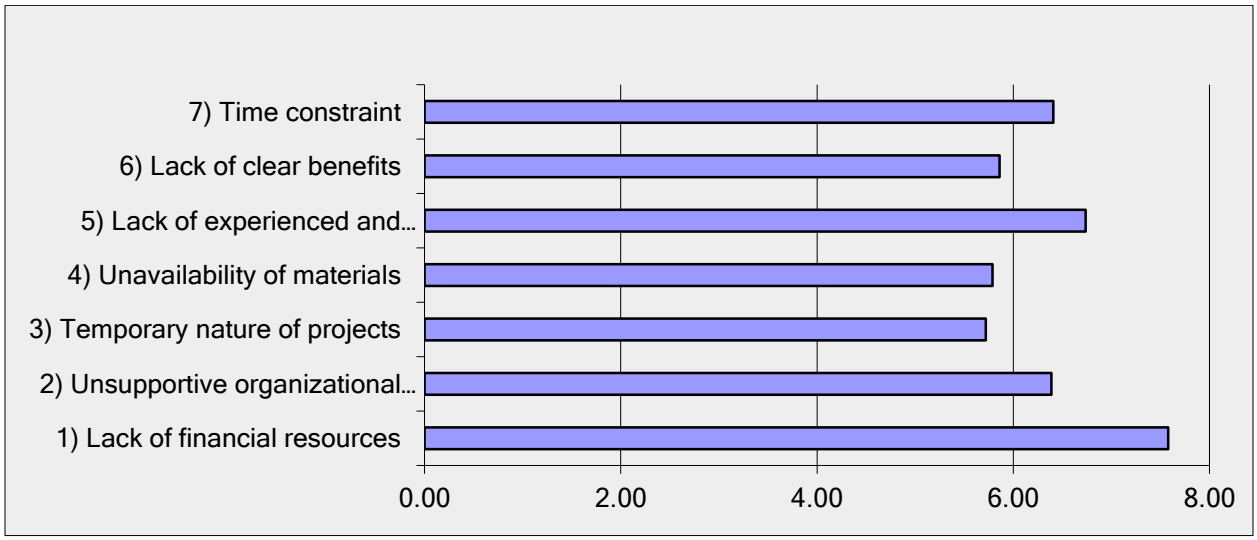

Figure4. 6 overall barrier factors survey results chart

Next component in the innovation process is the innovation input. This consists of 6 different factors assigned to be the main innovation input factors. Here, the ratings are capital with average rating of 7.42 out of 9, investment in R&D with 6.09, internal knowledge management with 6.15, external knowledge management with 6.09, consultancy with 6.25, and innovation team with 7.06 weight out of 9 as described and shown in table 4.4 and figure 4.7.

Table 4.4 Innovation input factors survey results

Please indicate the impact level of each listed input factor to initiate innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; (1 - lowest/minor impact 9 - highest impact) Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Capital	0	2	4	3	9	11	14	18	45	7.42	106
2) Investment in R&D	1	4	3	11	23	19	14	22	9	6.09	106
3) Internal knowledge management	0	2	6	11	23	14	21	21	8	6.15	106
4) External knowledge management	1	2	4	9	19	29	16	22	4	6.09	106
5) Consultancy	1	2	2	13	20	19	18	20	11	6.25	106
6) Innovation team	0	3	3	6	13	14	10	23	34	7.06	106

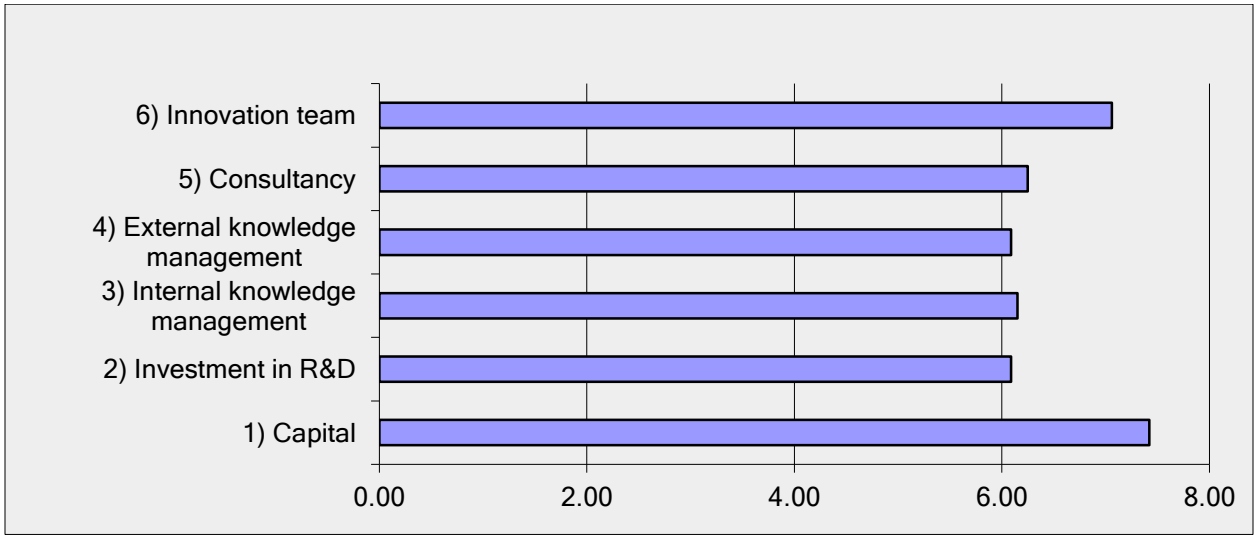

Figure4. 7 Innovation input factors survey chart

Innovation enabler component is also important component of innovation, which consists of 6 different factors assigned to It., The ratings of these six factors are effective cooperation with average rating of 7.16 out of 9, early contractor involvement with 6.28, leadership with 7.75, commitment with 7.08, reward schemes with 6.30, and training policy with 6.7 weight out of 9. The calculations are described and shown in table 4.5 and figure 4.8.

Table 4.5 Innovation enabler factors survey results

Please indicate the impact level of each listed enabler factor to implement innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Effective Cooperation	1	1	3	7	7	6	27	27	27	7.16	106
2) Early Contractor Involvement	2	3	2	10	22	16	18	17	16	6.28	106
3) Leadership	0	1	1	5	2	11	15	23	48	7.75	106
4) Commitment	1	1	1	10	5	17	20	22	29	7.08	106
5) Reward schemes	1	3	5	6	16	20	25	23	7	6.30	106
6) Training Policy	0	3	7	7	11	14	18	24	22	6.70	106

4.4 Type of innovation

Another important component of innovation process is the innovation model which produces the results. The components of this major driver are modern methods of construction with average rating of 7.63, project management tools with 6.28, strategic partnering with 6.07, supply chain partnership with 5.76, energy efficiency/sustainability with score of6.00, building information modeling (BIM) with 6.71 score, advanced materials with 6.95, lean construction with 6.22, automation with 6.91, and marketing with 5.83. All these scores are out of 9 and the calculations are described in table 4.6 and figure 4.8.

Table 4.6 models of innovation process survey results

Please indicate the impact level of each listed innovation type to implement innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Modern methods of construction	1	0	2	1	11	3	18	26	40	7.63	102
2) Project management tools	4	12	3	3	10	12	16	20	22	6.28	102
3) Strategic partnering	1	10	4	7	16	13	21	17	13	6.07	102
4) Supply chain partnership	2	9	3	9	18	25	16	9	11	5.76	102
5) Energy efficiency/ sustainability	1	5	4	12	15	23	16	18	8	6.00	102
6) Building information modeling (BIM)	0	3	3	9	13	14	19	18	23	6.71	102
7) Advanced materials	1	0	4	2	17	10	22	25	21	6.95	102
8) Lean construction	0	1	7	12	15	19	23	12	13	6.22	102
9) Automation	0	2	3	10	6	12	25	21	23	6.91	102
10) Marketing	4	9	5	7	16	12	26	11	12	5.83	102

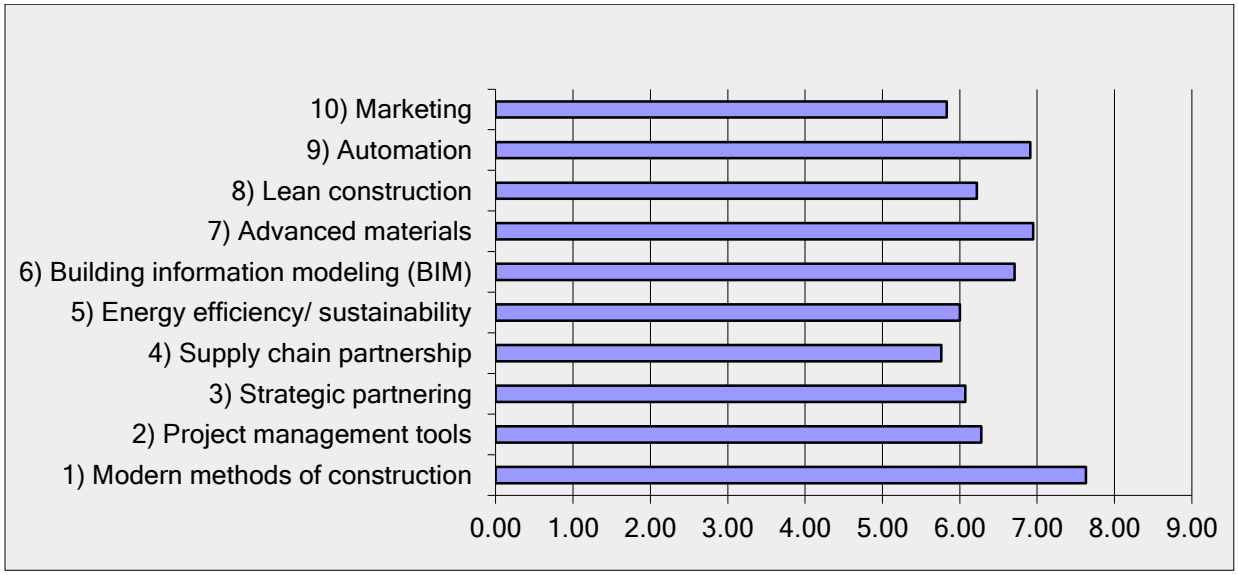

Figure4. 8 Innovation models chart

4.4 Innovation Output

Innovation results are described in this study by studying the innovation output. It consists of 4 different innovation outputs assigned to the main innovation outcome, these sub-factors are led by shorter project duration with average rating of 7.39 out of 9, followed by increased productivity with 7.64, improved technical and managerial capability with 6.52, and enhanced design trends with 6.6 weight out of 9. Table 4.7 and figure 4.9 present the calculations for above-mentioned results

Table 4.7 Innovation output factors survey results

Please indicate the impact level of each listed output factor on innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Shorter project duration	0	1	5	2	11	7	16	20	40	7.39	102
2) Increased productivity	0	0	3	6	5	5	20	16	47	7.64	102
3) Improved technical and managerial capability	1	0	3	8	17	24	14	19	16	6.52	102
4) Enhanced design trends	1	1	2	6	15	20	23	22	12	6.60	102

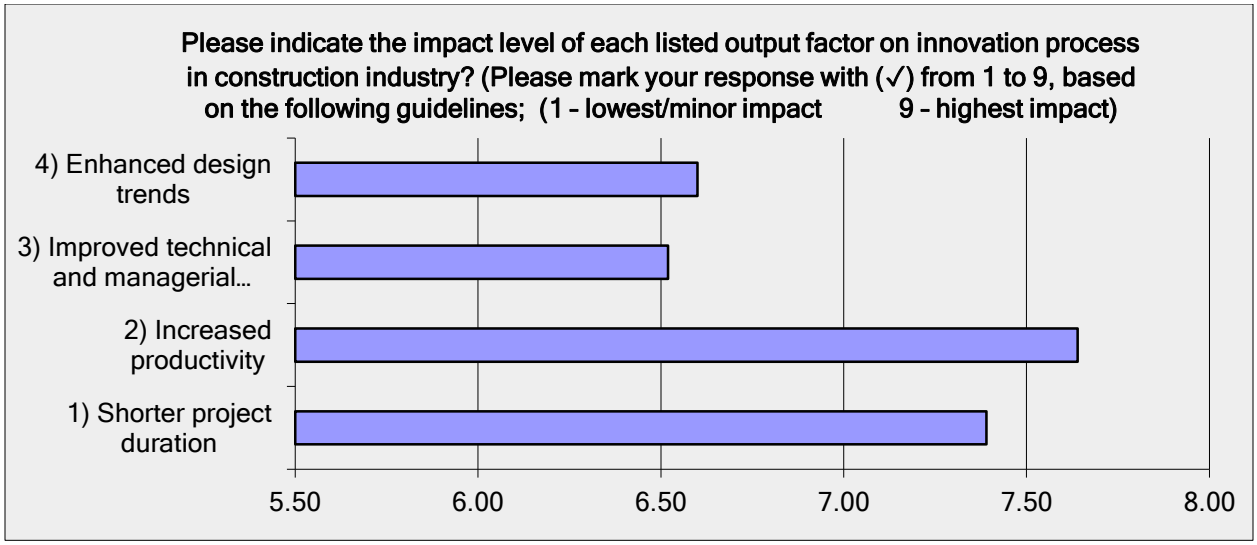

Figure4. 9 Innovation output factors chart

Chapter 5

Research analysis and discussion

5.1 Introduction

In this chapter, analysis result of the collected data collected is discussed using AHP method. The first step of AHP is to score the arranged factors based on table 3.1, and construct different matrices for each innovation category in each construction organization. There are 7 different categories with 5 different construction organizations, which mean that 35 matrices are constructed to evaluate the 46 factors. The scores of different factors are normalized to convert into percentages. The next stage involves finding the average of the matrices rows, which are the percentages of each factor compared to other factors. The last step in AHP method was to multiply each factor in each organization by its organization weight extracted from the total rating average of all innovation factors for each construction organization. Finally, summation of scores of each factor multiplied to their relative organization weight gives the ranking of each factor.

5.2 Weight of construction organization involvement

The weight of construction organizations and their involvement level in innovation process is based on assumption of that the higher score of innovation factors for any organization means the involvement of that organization in innovation is higher. This means that construction organization with higher average ranking values for all 46 innovation factors will have a higher weight in with respect to its involvement in construction innovation process. All innovation factors discussed in the project are important and affect the innovation process. The construction

organizations who have rated the factors of innovation process with high values are more familiar and involved in the innovation process due to their better understanding of importance of innovation in construction. Table 5.1 shows the average values of all innovation factors related to each construction organization. The average is calculated by having summation of all 46 factors values for each organization and divided by the number of factors used in the study.

$$Avg = \frac{\sum Fij}{No.of\ factors}$$

Fi : value of factor i, where i= 1,2,3,4….46

j: related to construction organization where j=1,2,3,4,5

No. of factors = 46 factors

Table 5. 1 Average rating of total innovation factors

Construction Organization	Total average rank
Consultant	6.887
PM	6.717
Owner	6.65
Contractor	6.444
Supplier	6.213

It is noticed that the consultant obtained the highest average ranking value, and the supplier obtained the lowest average ranking value for innovation factors. From the results, it can be concluded that the consultant and project management organizations have the highest impact on

innovation process in construction industry. Its makes sense as these organizations have the opportunity of using knowledge from variety of projects. Also, the main objective of fulfilling the client and market requirements allows them to initiate innovation from the beginning of construction projects

AHP process is applied to score the construction organizations with each other using table 2.1. Table 5.2 summarize the matrix resulted from the pairwise comparison for construction organizations.

Table 5. 2 pairwise comparison matrix for construction organizations

	Contractor	Consultant	Project management	Owner	Supplier
Contractor	1.0	0.143	0.200	0.333	3.0
Consultant	7.0	1.0	3.0	5.0	9.0
Project management	5.0	0.333	1.0	3.0	7.0
Owner	3.0	0.200	0.333	1.0	5.0
Supplier	0.333	0.111	0.143	0.200	1.0

The next step after developing the pair wise comparison matrix is normalizing each column in the developed matrix, and then the average of each row is computed to end up with the weight percentage of each organization's involvement in innovation process. Table 5.3 summarizes the AHP result for each organization and figure 5.1 summarizes the weight of involvement of each organization in innovation process.

Table 5. 3 Construction organizations weight

	Contractor	Consultant	Project management	Owner	Supplier	Average	%
Contractor	0.061	0.080	0.043	0.035	0.120	0.068	6.78
Consultant	0.429	0.560	0.642	0.524	0.360	0.503	50.28
Project management	0.306	0.187	0.214	0.315	0.280	0.260	26.02
Owner	0.184	0.112	0.071	0.105	0.200	0.134	13.44
Supplier	0.020	0.062	0.031	0.021	0.040	0.035	3.48

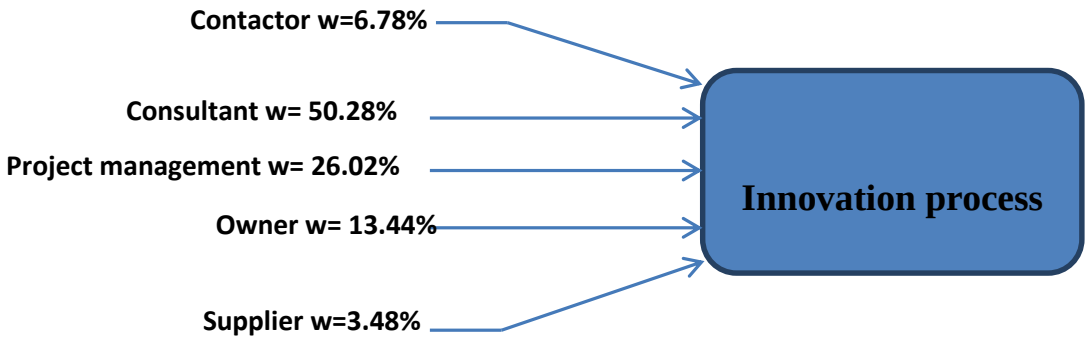

Figure 5. 1 Weight of each construction organization

5.3 Analysis methodology

The survey output summarized in chapter 4 represents the overall survey result including all participants from all construction organizations. To apply AHP method the data should be filtered to overview each organization point of view related to the innovation factors. Total respondents for the survey are 121, which are divided into 53 contractors, 15 consultants, 21

project management consultants, 17 owners, and 15 suppliers. The data extracted from the survey report for each organization response is used in AHP method as shown in Appendix B. Innovation factors are then arranged according to their impact level compared to each other, and then the scoring method is applied to the innovation factors and matrices are constructed for the pairwise comparison. Therefore, all matrices are established for all innovation factors to apply AHP analysis. Figure 5.2 shows the analysis methodology steps and procedures.

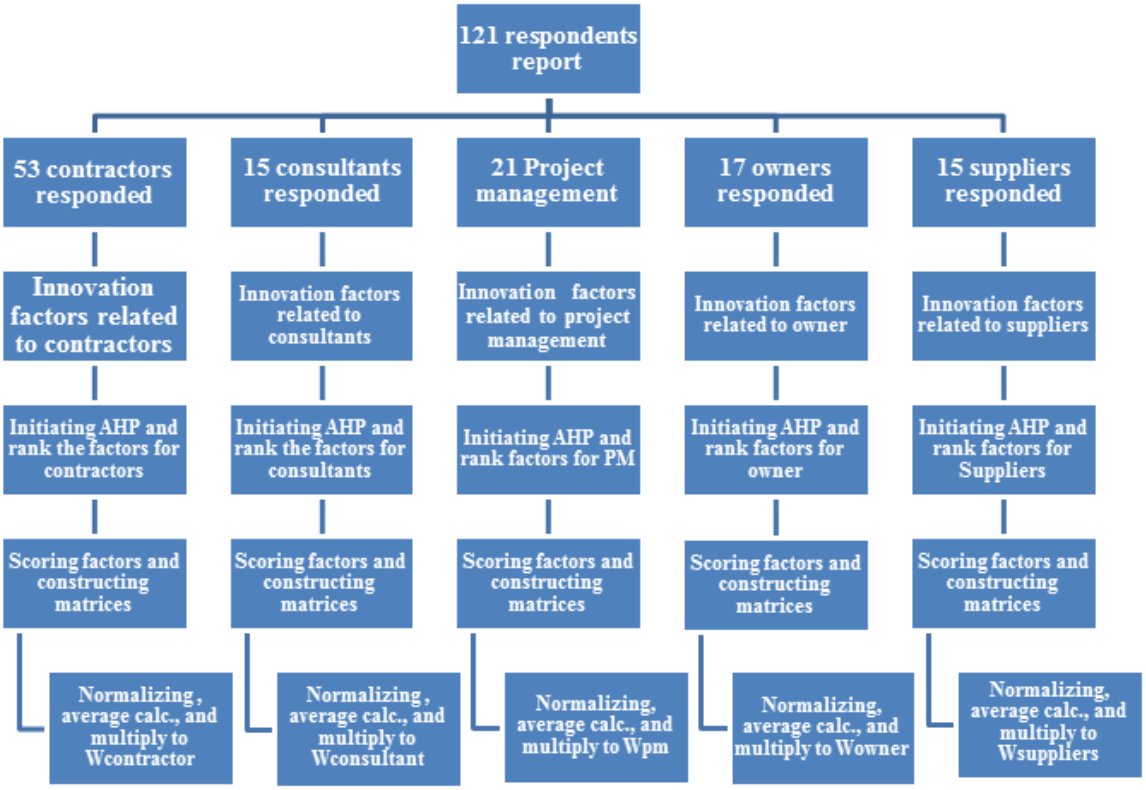

Figure 5. 2 Analysis methodology

5.4 Analytical hierarchy process

After compiling all survey data, responses from different construction organizations are categorized, and rank each construction organization according to pair wise comparison for innovation factor relative to is done to obtain the rakings of innovation factors with respect to each organization considering that all 46 innovation factors are independent to each other. This process is repeated for all seven categories for each construction organization to end up with 35 matrices. The factors will be scored based on table 3.1 ranking table. The next step involved normalizing the matrices by having the summation for each matrix column, and then dividing each αij by the column summation to end up with normalized matrices. After normalizing the factors, matrices average was calculated for each row in each matrix to end up with the rank values for the innovation factors in each construction organization. The last step is to integrate all ranking values for all construction organizations together based on their relative weight with respect to innovation involvement percentage weight of each construction organization; figure 5.3 summarizes the AHP procedure and steps.

Step 1: pair wise comparison and scoring between each factor to another

Step 2: construct matrices for the innovation factors

$$\begin{array}{c} \\ F1 \\ F2 \\ F3 \\ F4 \\ Fj \end{array}\begin{array}{c} \begin{array}{cccc} F1 & F2 & F3 & Fj \end{array} \\ \begin{bmatrix} \alpha 11 & \alpha 12 & \alpha 13 & \ldots.. \\ \alpha 21 & \alpha 22 & \alpha 23 & \ldots.. \\ \alpha 31 & \alpha 32 & \alpha 33 & \ldots.. \\ \alpha 41 & \alpha 42 & \alpha 43 & \ldots.. \\ \ldots. & \ldots. & \ldots. & \alpha jj \end{bmatrix} \end{array}$$

$\alpha 11, \alpha 22, \alpha 33, \ldots \alpha jj = 1$

$\alpha 12 = X, \alpha 21 = 1/X$, where X(score) =1,2,..or 9

Step 3: Normalizing each column in a matrix

$$\begin{array}{c} \\ F1 \\ F2 \\ F3 \\ F4 \\ Fj \\ \textbf{Total} \end{array}\begin{array}{c} \begin{array}{cccc} F1 & F2 & F3 & Fj \end{array} \\ \begin{bmatrix} \alpha 11/TF1 & \alpha 12/TF2 & \alpha 13/TF3 & \ldots.. \\ \alpha 21/TF1 & \alpha 22/TF2 & \alpha 23/TF3 & \ldots.. \\ \alpha 31/TF1 & \alpha 32/TF2 & \alpha 33/TF3 & \ldots.. \\ \alpha 41/TF1 & \alpha 42/TF2 & \alpha 43/TF3 & \ldots.. \\ \ldots. & \ldots. & \ldots. & \alpha jj/TFJ \\ TF1 & TF2 & TF3 & TFj \end{bmatrix} \end{array}$$

TF1= $\alpha 11 + \alpha 21 + \alpha 31 + \ldots + \alpha 1j$

TF2= $\alpha 12 + \alpha 22 + \alpha 32 + \ldots + \alpha 2j$

TFj= $\alpha 1j + \alpha 2j + \alpha 3j + \ldots + \alpha jj$

Step 4: Row average for each innovation factor

$$\begin{array}{c} \\ F1 \\ F2 \\ F3 \\ F4 \\ Fj \end{array}\begin{array}{c} \begin{array}{cccc} F1 & F2 & F3 & Fj \end{array} \\ \begin{bmatrix} N11 & N12 & N13 & \ldots.. \\ N21 & N22 & N23 & \ldots.. \\ N31 & N32 & N33 & \ldots.. \\ N41 & N42 & N43 & \ldots.. \\ \ldots. & \ldots. & \ldots. & Njj \end{bmatrix} \end{array} \Rightarrow \begin{array}{c} \\ F1 \\ F2 \\ F3 \\ F4 \\ Fj \end{array}\begin{bmatrix} AVG.F1 \\ AVG.F2 \\ AVG.F3 \\ AVG.F4 \\ AVG.FJ \end{bmatrix}$$

AVG.F1 (average rank for factor 1)

$$= \frac{N11+N12+N13+\cdots+N1J}{J}$$

AVG.F2 (average rank for factor 2)

$$= \frac{N21+N22+N23+\cdots+N2J}{J}$$

AVG.FJ (average rank for factor J)

$$= \frac{NJ1+NJ2+NJ3+\cdots+NJJ}{J}$$

Step 5: Overall ranking

$$Si = \sum gij \times Wj$$

Overall ranking for Fj= Avg.Fj (contractor) x W_{cont} + Avg.Fj (consultant) x $W_{cons.}$+ Avg.Fj (PM) x W_{PM} + Avg.Fj (Owner) x W_{owner}+ Avg.Fj (Supplier) x $W_{supplier}$

Figure 5. 3 AHP steps and summary

5.4.1 AHP matrices and scoring the innovation factors

As previously discussed the pair wise comparison between each construction organization innovation factors are approached through constructing different matrices for different innovation categories which are 1- general innovation outcome, 2- innovation driver factors, 3- innovation barriers factors, 4- innovation input factors, 5- innovation enablers factors, 6- models of innovation practices,7- innovation output factors. Therefore, for each construction organization there will be seven matrices, table 5.1 to table 5.7 summarize the AHP matrices and the scores for contractors' participants, and appendix C summarize the matrices and the scores for all other construction organizations.

Table 5. 4 Scoring matrix for innovation impact factors for contractor

	Contractor					
	Cost saving	Time saving	Quality improvement	Technology improvement	Construction safety	Market improvement
1) Cost saving	1	0.333	0.5	5	2	3
2) Time saving	3	1	2	9	5	7
3) Quality improvement	2	0.50	1	7	3	5
4) Technology improvement	0.2	0.111	0.143	1	0.333	0.5
5) Construction safety improvement	0.5	0.2	0.333	3	1	2
6) Market improvement	0.333	0.143	0.2	2	0.5	1

Table 5. 5 Scoring matrix for innovation driver's factors for contractor

	Contractor						
	Client requirement	Competition level	Project performance level	Regulation and legislation	Knowledge exchange	Design trends	Environment and sustainability
1) Client requirement	1	3	2	8	9	5	7
2) Competition level	0.333	1	0.5	5	7	2	3
3) Project performance improvement	0.5	2	1	7	8	3	5
4) Regulation and legislation	0.125	0.2	0.143	1	2	0.333	0.5
5) Knowledge exchange	0.111	0.143	0.125	0.5	1	0.2	0.333
6) Design trends	0.2	0.5	0.333	3	5	1	2
7) Environment and sustainability	0.143	0.333	0.200	2	3	0.5	1

Table 5. 6 Scoring matrix for innovation barriers factors for contractor

	Contractor						
	Lack of financial resources	Unsupportive organizational culture	Temporary nature of projects	Unavailability of materials	Lack of experienced and qualified staff	Lack of clear benefits	Time constraint
1) Lack of financial resources	1	8	9	5	2	7	3

2) Unsupportive organizational culture	0.125	1	2	0.333	0.143	0.5	0.2
3) Temporary nature of projects	0.111	0.5	1	0.2	0.125	0.333	0.143
4) Unavailability of materials	0.2	3	5	1	0.333	2	0.5
5) Lack of experienced and qualified staff	0.5	7	8	3	1	5	2
6) Lack of clear benefits	0.143	2	3	0.5	0.2	1	0.333
7) Time constraint	0.333	5	7	2	0.5	3	1

Table 5. 7 Scoring matrix for innovation input factors for contractor

	Contractor					
	Capital	Investment in R&D	Internal knowledge management	External knowledge management	Consultancy	Innovation team
1) Capital	1	9	5	7	3	2
2) Investment in R&D	0.111	1	0.333	0.500	0.2	0.143
3) Internal knowledge management	0.2	3	1	2	0.5	0.333
4) External knowledge management	0.143	2	0.5	1	0.333	0.2
5) Consultancy	0.333	5	2	3	1	0.5
6) Innovation team	0.5	7	3	5	2	1

Table 5. 8 Scoring matrix for innovation enabler's factors for contractor

	Contractor					
	Effective Cooperation	Early Contractor Involvement	Leadership	Commitment	Reward schemes	Training Policy
1) Effective Cooperation	1	5	0.5	2	7	3
2) Early Contractor Involvement	0.2	1	0.143	0.333	2	0.5
3) Leadership	2	7	1	3	9	5
4) Commitment	0.5	3	0.333	1	5	2
5) Reward schemes	0.143	0.5	0.111	0.2	1	0.333
6) Training Policy	0.333	2	0.2	0.5	3	1

Table 5. 9 Scoring matrix for innovation models factors, contractor

	Contractor									
	Modern method of construction	Project management tools	Strategic partnering	Supply chain partnership	Energy efficiency/ sustainability	Building information modeling (BIM)	Advanced materials	Lean construction	Automation	Marketing
1) Modern methods of construction	1	6	7	10	8	5	3	4	2	9
2) Project management tools	0.167	1	2	5	3	0.5	0.25	0.333	0.2	4
3) Strategic partnering	0.143	0.5	1	4	2	0.333	0.2	0.25	0.167	3
4) Supply chain partnership	0.1	0.2	0.25	1	0.333	0.167	0.125	0.143	0.111	0.5

5) Energy efficiency/ sustainability	0.125	0.333	0.5	3	1	0.25	0.167	0.2	0.143	2
6) Building information modeling (BIM)	0.2	2	3	6	4	1	0.333	0.5	0.25	5
7) Advanced materials	0.333	4	5	8	6	3	1	2	0.5	7
8) Lean construction	0.25	3	4	7	5	2	0.5	1	0.333	6
9) Automation	0.5	5	6	9	7	4	2	3	1	8
10) Marketing	0.111	0.25	0.333	2	0.5	0.2	0.143	0.167	0.125	1

Table 5. 10 Scoring matrix for innovation output factors for contractor

	Contractor			
	Short project duration	Increased productivity	Improved technical and managerial	Enhanced design trends
1) Shorter project duration	1	0.333	7	3
2) Increased productivity	3	1	9	7
3) Improved technical and managerial capability	0.143	0.111	1	0.333
4) Enhanced design trends	0.333	0.143	3	1

5.4.2 Innovation factors normalizing

After constructing the matrices for all innovation factors in all construction organizations and the pair wise comparison of factors based on the scoring table, the next step is to normalize the matrices by dividing each factor rank in column by the summation of each column related to its

specified matrix, table 5.8 to table 5.14 summarize the normalized matrices for the contractors' participants, and appendix D for the rest construction organizations

Table 5. 11 Normalized matrix for innovation impact factors, contractor

	Contractor (Normalized)					
	Cost saving	Time saving	Quality improvement	Technology improvement	Construction safety	Market improvement
1) Cost saving	0.142	0.146	0.120	0.185	0.169	0.162
2) Time saving	0.427	0.437	0.479	0.333	0.423	0.378
3) Quality improvement	0.284	0.219	0.239	0.259	0.254	0.270
4) Technology improvement	0.028	0.049	0.034	0.037	0.028	0.027
5) Construction safety improvement	0.071	0.087	0.080	0.111	0.085	0.108
6) Market improvement	0.047	0.062	0.048	0.074	0.042	0.054

Table 5. 12 Normalized matrix for innovation driver's factors, contractor

	Contractor (Normalized)						
	Client requirement	Competition level	Project performance level	Regulation and legislation	Knowledge exchange	Design trends	Environment and sustainability
1) Client requirement	0.415	0.418	0.465	0.302	0.257	0.416	0.372
2) Competition level	0.138	0.139	0.116	0.189	0.200	0.166	0.159
3) Project performance improvement	0.207	0.279	0.232	0.264	0.229	0.249	0.265
4)	0.052	0.028	0.033	0.038	0.057	0.028	0.027

Regulation and legislation							
5) Knowledge exchange	0.046	0.020	0.029	0.019	0.029	0.017	0.018
6) Design trends	0.083	0.070	0.077	0.113	0.143	0.083	0.106
7) Environment and sustainability	0.059	0.046	0.046	0.075	0.086	0.042	0.053

Table 5. 13 Normalized matrix for innovation barrier's factors, contractor

	Contractor (Normalized)						
	Lack of financial resources	Unsupportive organizational culture	Temporary nature of projects	Unavailability of materials	Lack of experienced and qualified	Lack of clear benefits	Time constraint
1) Lack of financial resources	0.415	0.302	0.257	0.416	0.465	0.372	0.418
2) Unsupportive organizational culture	0.052	0.038	0.057	0.028	0.033	0.027	0.028
3) Temporary nature of projects	0.046	0.019	0.029	0.017	0.029	0.018	0.020
4) Unavailability of materials	0.083	0.113	0.143	0.083	0.077	0.106	0.070
5) Lack of experienced and qualified staff	0.207	0.264	0.229	0.249	0.232	0.265	0.279
6) Lack of clear benefits	0.059	0.075	0.086	0.042	0.046	0.053	0.046
7) Time constraint	0.138	0.189	0.200	0.166	0.116	0.159	0.139

Table 5. 14 Normalized matrix for innovation input factors, contractor

Contractor (Normalized)						
	Capital	Investment in R&D	Internal knowledge management	External knowledge management	Consultancy	Innovation team
1) Capital	0.437	0.333	0.423	0.378	0.427	0.479
2) Investment in R&D	0.049	0.037	0.028	0.027	0.028	0.034
3) Internal knowledge management	0.087	0.111	0.085	0.108	0.071	0.080
4) External knowledge management	0.062	0.074	0.042	0.054	0.047	0.048
5) Consultancy	0.146	0.185	0.169	0.162	0.142	0.120
6) Innovation team	0.219	0.259	0.254	0.270	0.284	0.239

Table 5. 15 Normalized matrix for innovation enabler's factors, contractor

Contractor (Normalized)						
	Effective Cooperation	Early Contractor Involvement	Leadership	Commitment	Reward schemes	Training Policy
1) Effective Cooperation	0.239	0.270	0.219	0.284	0.259	0.254
2) Early Contractor Involvement	0.048	0.054	0.062	0.047	0.074	0.042
3) Leadership	0.479	0.378	0.437	0.427	0.333	0.423

4) Commitment	0.120	0.162	0.146	0.142	0.185	0.169
5) Reward schemes	0.034	0.027	0.049	0.028	0.037	0.028
6) Training Policy	0.080	0.108	0.087	0.071	0.111	0.085

Table 5. 16 Normalized matrix for innovation models factors, contractor

	Contractor (Normalized)									
	Modern methods of construction	Project management tools	Strategic partnering	Supply chain partnership	Energy efficiency / sustainability	Building information modeling (BIM)	Advanced materials	Lean construction	Automation	Marketing
1) Modern methods of construction	0.341	0.269	0.241	0.182	0.217	0.304	0.389	0.345	0.414	0.198
2) Project management tools	0.057	0.045	0.069	0.091	0.081	0.030	0.032	0.029	0.041	0.088
3) Strategic partnering	0.049	0.022	0.034	0.073	0.054	0.020	0.026	0.022	0.035	0.066
4) Supply chain partnership	0.034	0.009	0.009	0.018	0.009	0.010	0.016	0.012	0.023	0.011
5) Energy efficiency/ sustainability	0.043	0.015	0.017	0.055	0.027	0.015	0.022	0.017	0.030	0.044
6) Building information modeling (BIM)	0.068	0.090	0.103	0.109	0.109	0.061	0.043	0.043	0.052	0.110
7) Advanced materials	0.114	0.180	0.172	0.145	0.163	0.182	0.130	0.173	0.104	0.154
8) Lean construction	0.085	0.135	0.138	0.127	0.136	0.122	0.065	0.086	0.069	0.132
9) Automation	0.171	0.224	0.206	0.164	0.190	0.243	0.259	0.259	0.207	0.176
10) Marketing	0.038	0.011	0.011	0.036	0.014	0.012	0.019	0.014	0.026	0.022

Table 5. 17 Normalized matrix for innovation output factors, contractor

	Contractor (Normalized)			
	Short project duration	Increased productivity	Improved technical and managerial	Enhanced design trends
1) Shorter project duration	0.223	0.210	0.350	0.265
2) Increased productivity	0.670	0.630	0.450	0.618
3) Improved technical and managerial capability	0.032	0.070	0.050	0.029
4) Enhanced design trends	0.074	0.090	0.150	0.088

5.4.3 Overall ranking

This chapter describes the final stage of AHP process, which collates all innovation factors ranking with the weight of involvement of organizations in the innovation process. The values obtained from the normalized matrices are added all together for each factor and divided by the number of comparisons executed for that factor to end up with the average ranking for innovation factors with respect to each organization. Table 5.15 summarizes the average ranking of each innovation factor with respect to contractor. Appendix E summarizes the average ranking of innovation factors with respect to the other construction organizations. Finally, the weight concluded from the survey data, which is shown in figure 5.1, is multiplied to its related innovation factor value as shown in figure 5.3 to obtain table 5.16 which is the overall ranking for each innovation factor. This ranking is with respect to the level of importance and correlation of each construction organization to the innovation process.

Table 5. 18 Average ranking for innovation factors with respect to contractor view

Contractor (w=6.78%)	
General Innovation outcome	
	AVERAGE
1) Cost saving	0.154
2) Time saving	0.413
3) Quality improvement	0.254
4) Technology improvement	0.034
5) Construction safety improvement	0.090
6) Market improvement	0.055
Innovation driver factors	
	AVERAGE
1) Client requirement	0.378
2) Competition level	0.158
3) Project performance improvement	0.247
4) Regulation and legislation	0.037
5) Knowledge exchange	0.025
6) Design trends	0.096
7) Environment and sustainability	0.058
Innovation barriers factors	
	AVERAGE
1) Lack of financial resources	0.378
2) Unsupportive organizational culture	0.037
3) Temporary nature of projects	0.025
4) Unavailability of materials	0.096
5) Lack of experienced and qualified staff	0.247
6) Lack of clear benefits	0.058
7) Time constraint	0.158
Innovation input factors	
	AVERAGE
1) Capital	0.413
2) Investment in R&D	0.034
3) Internal knowledge management	0.090

4) External knowledge management	0.055
5) Consultancy	0.154
6) Innovation team	0.254
Innovation enablers factors	
	AVERAGE
1) Effective Cooperation	0.254
2) Early Contractor Involvement	0.055
3) Leadership	0.413
4) Commitment	0.154
5) Reward schemes	0.034
6) Training Policy	0.090
Models of innovation practices	
	AVERAGE
1) Modern methods of construction	0.290
2) Project management tools	0.056
3) Strategic partnering	0.040
4) Supply chain partnership	0.015
5) Energy efficiency/ sustainability	0.028
6) Building information modeling (BIM)	0.079
7) Advanced materials	0.152
8) Lean construction	0.109
9) Automation	0.210
10) Marketing	0.020
Innovation output factors	
	AVERAGE
1) Shorter project duration	0.262
2) Increased productivity	0.592
3) Improved technical and managerial capability	0.045
4) Enhanced design trends	0.101

Table 5. 19 Overall ranking values for innovation factors

Overall ranking	
1) Cost saving	0.236
2) Time saving	0.434
3) Quality improvement	0.154
4) Technology improvement	0.037
5) Construction safety improvement	0.089
6) Market improvement	0.050
	Average
1) Client requirement	0.377
2) Competition level	0.076
3) Project performance improvement	0.197
4) Regulation and legislation	0.044
5) Knowledge exchange	0.031
6) Design trends	0.201
7) Environment and sustainability	0.075
	Average
1) Lack of financial resources	0.382
2) Unsupportive organizational culture	0.150
3) Temporary nature of projects	0.036
4) Unavailability of materials	0.030
5) Lack of experienced and qualified staff	0.241
6) Lack of clear benefits	0.058
7) Time	0.102

constraint	
	Average
1) Capital	0.410
2) Investment in R&D	0.085
3) Internal knowledge management	0.066
4) External knowledge management	0.079
5) Consultancy	0.153
6) Innovation team	0.210
	Average
1) Effective Cooperation	0.175
2) Early Contractor Involvement	0.039
3) Leadership	0.423
4) Commitment	0.209
5) Reward schemes	0.051
6) Training Policy	0.102
	Average
1) Modern methods of construction	0.220
2) Project management tools	0.159
3) Strategic partnering	0.084
4) Supply chain partnership	0.020
5) Energy efficiency/ sustainability	0.054
6) Building information modeling (BIM)	0.209
7) Advanced materials	0.095
8) Lean construction	0.032
9) Automation	0.100

10) Marketing	0.026
	Average
1) Shorter project duration	0.197
2) Increased productivity	0.539
3) Improved technical and managerial capability	0.171
4) Enhanced design trends	0.094

Chapter 6

Conclusion and recommendation

6.1 Objectives achievement

The project report is about studying the innovation process in different construction organizations by investigating the factors affecting the innovation process. The purpose of studying the innovation process for different construction organizations is to have real and detailed study of the innovation process in construction industry. This is because all construction organizations need to approach the innovation concept in construction industry with different importance level, for example consultant in the report analysis result is the most involved construction organization in the innovation process and has more weight. From that concept, the projects have different objectives approach and achievements and one of the achievements is to recognize which construction organization should be the most concerned in enhancing the innovation process. From the analysis of collected data, it is noticed that consultants have the highest weight of involvement in the innovation process and based on the collected factors, consultants are considered most effective organization that affect the innovation factors. Consultant organization has a weight of involvement of 50.2%; the next effective construction organization in the innovation process is project management organization with 26.02% score, next organization is owner representative with 13.44%, then contractor with 6.78%, and finally supplier with 3.48%. The next achievement in this research project is studying the ranking and involvement of the innovation factors for each construction organization. Figure 6.1 to Figure 6.5 show the summary of the innovation factors

ranking values for different construction organizations. The study results found almost close values of ranking of innovation factors to all construction organizations. This is due to the limitation in applying real innovation concepts in construction organizations. The data collected is mostly not really applied in their organizations but still the participants replied based on general perception of how the innovation would impact the construction projects.

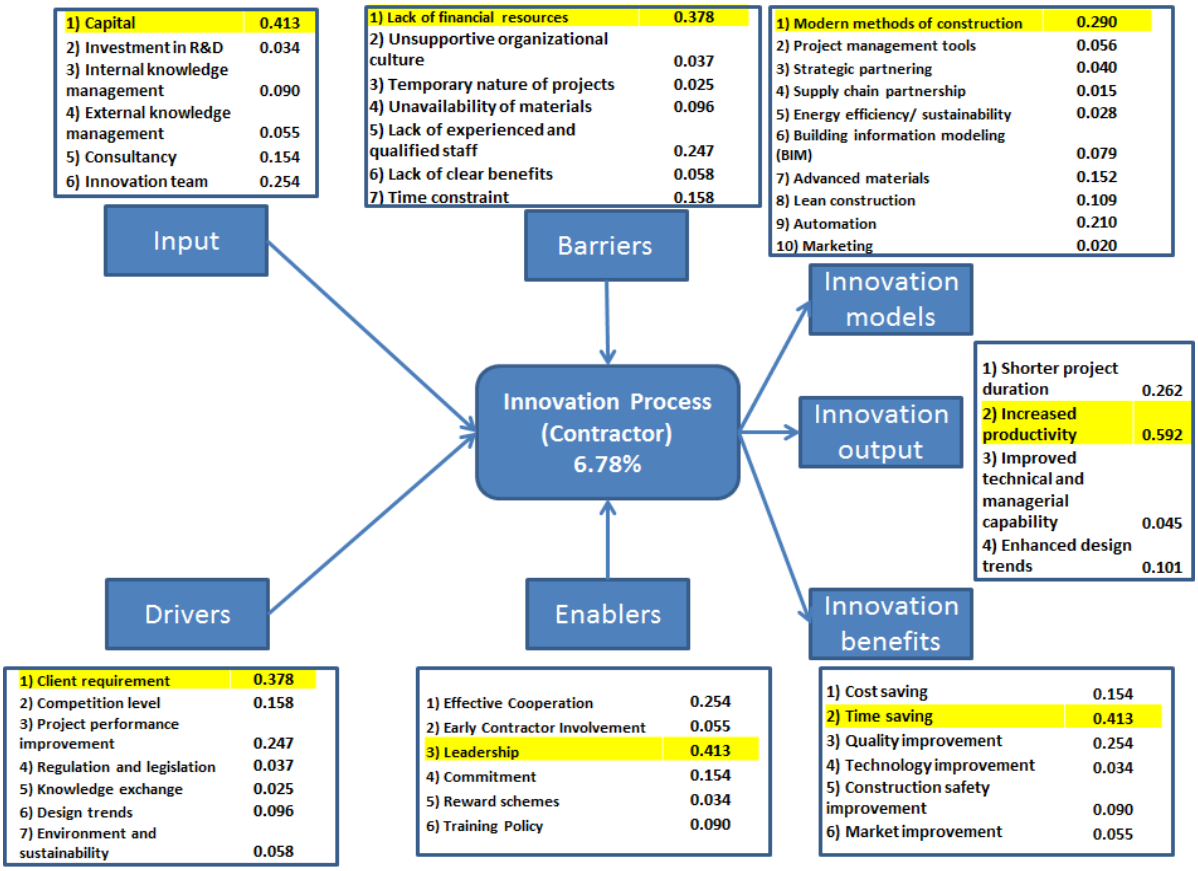

Figure 6. 1 Analysis results for contractor responses

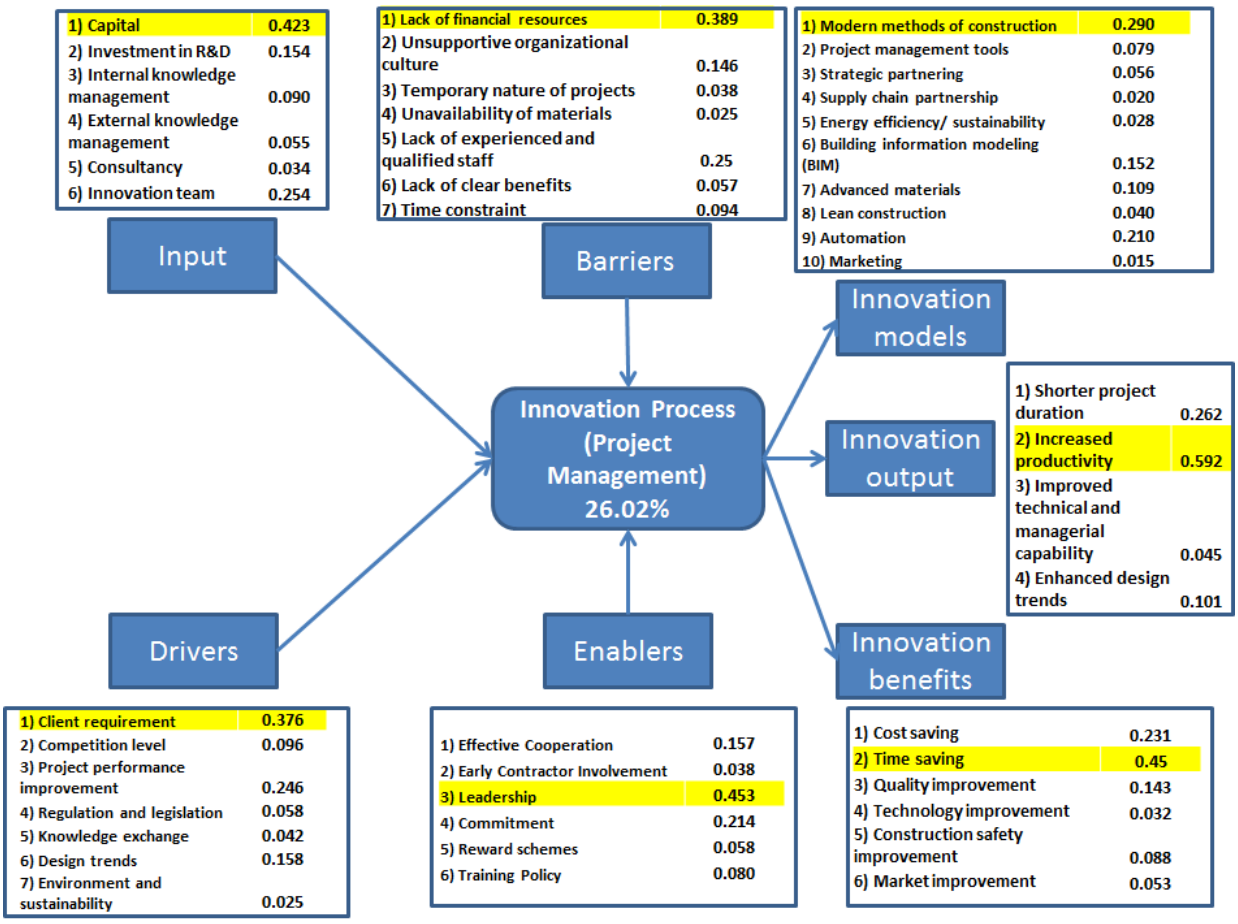

Figure 6. 2 Analysis results for PM results

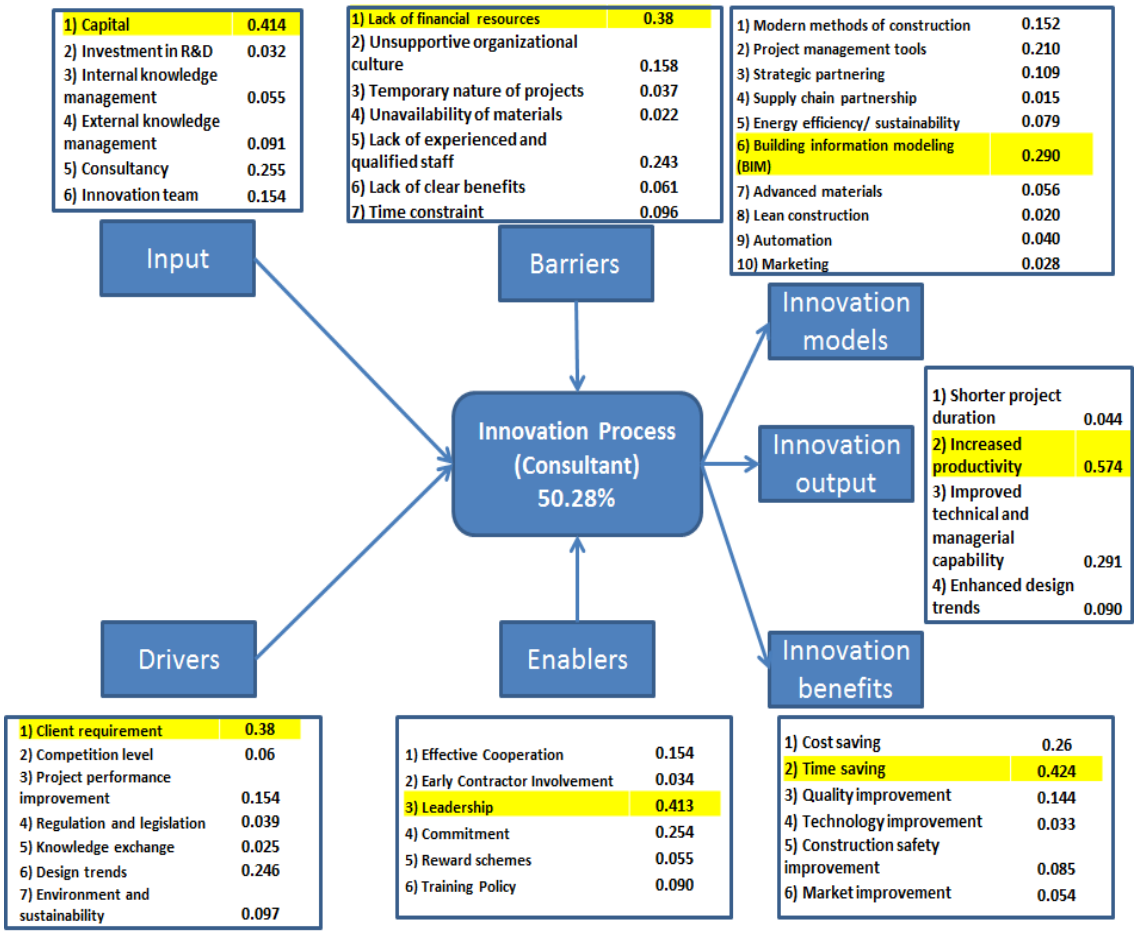

Figure 6. 3 Analysis results for Consultant responses

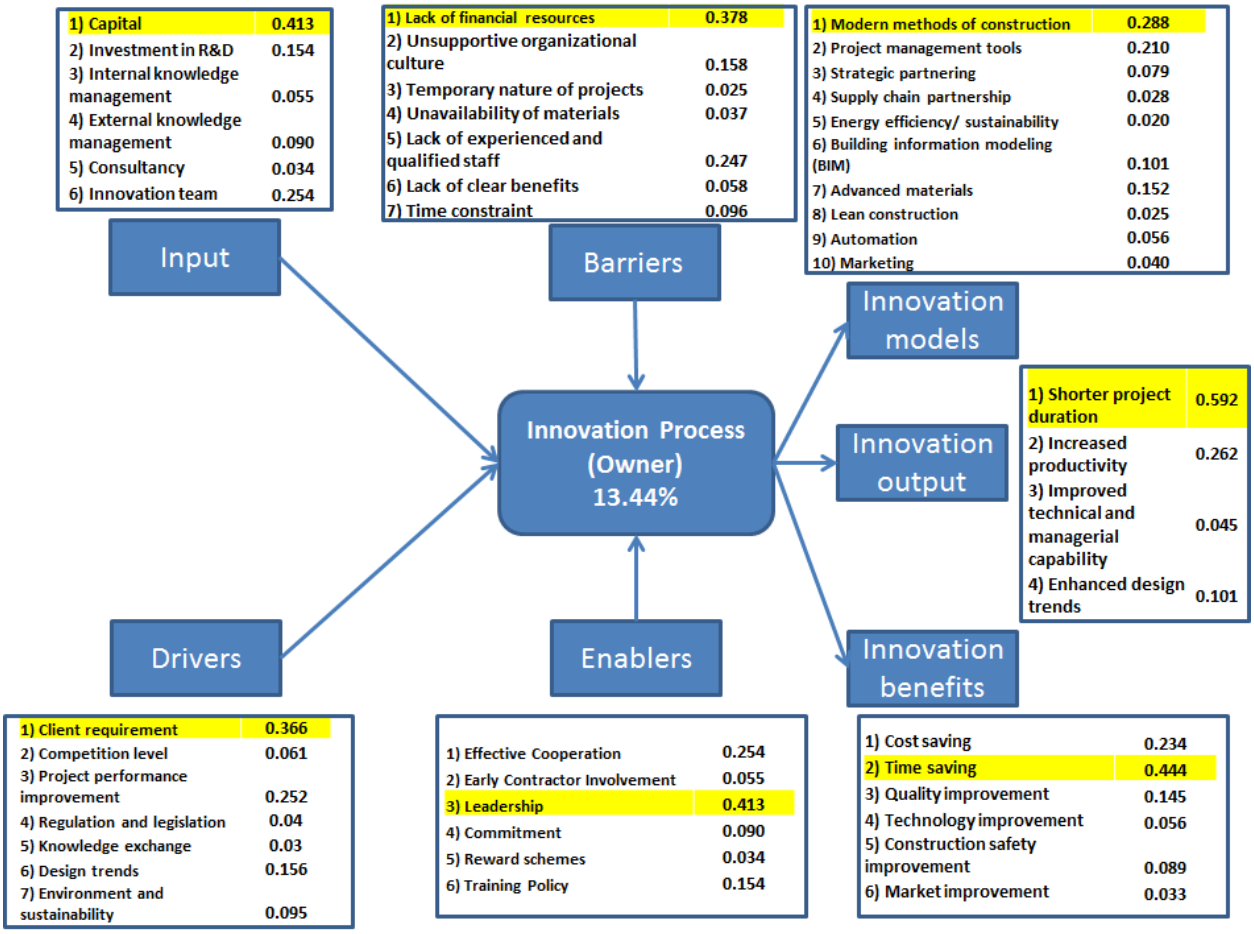

Figure 6. 4 Analysis results for owner responses

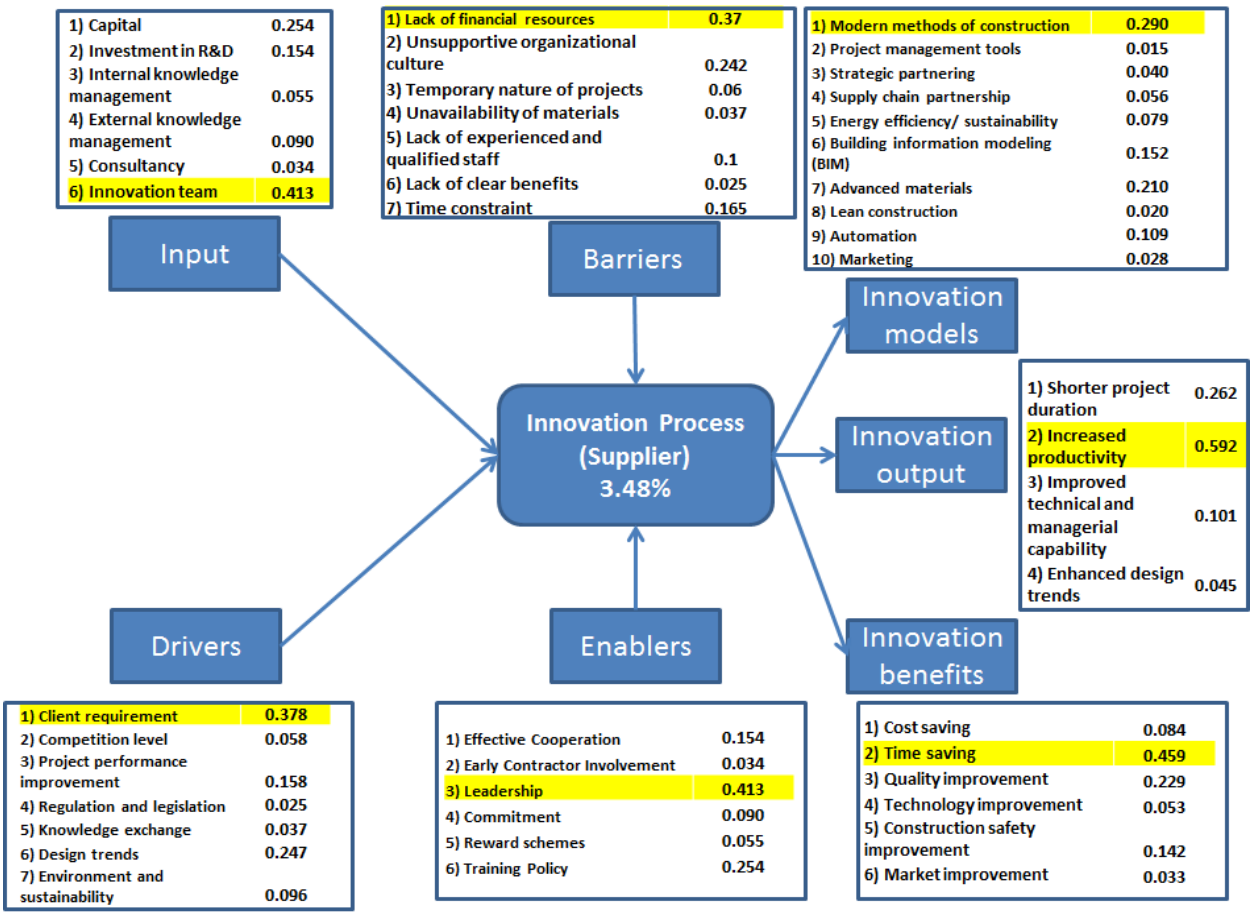

Figure 6. 5 Analysis results for Suppliers responses

6.2 Conclusion

From the analysis of collected data and literature review, it is concluded that the innovation process factors related to different construction organizations have values similar to each other. Figure 6.6 shows the overall ranking for the innovation factors with respect to different impact level of each construction organization in the innovation process. It is concluded that the most important input factor to initiate the innovation process is providing the enough capital and funding the innovation process. Moreover, it

is noticed that the major reason to initiate the innovation concept is the client requirement more than improving the construction process and improving the competitive dimension in the construction market. For example, Government and authorities in Qatar are considered as the clients and the innovation process as previously mentioned is assumed to be applied for huge scale objectives. The major obstacle to initiate the innovation process as per the data analysis is the shortage of financial support and resources to motivate and initiate the innovation practices. These are all external impact to innovation process. The internal impacts studied in this report consider leadership as the most important factor that should be carefully applied in the innovation process. Finally, as per client requirements and country's vision, it is found that having new and modern methods of construction is the best innovation approach to achieve the organizational goals of increasing the productivity and hence finishing the projects earlier to save time.

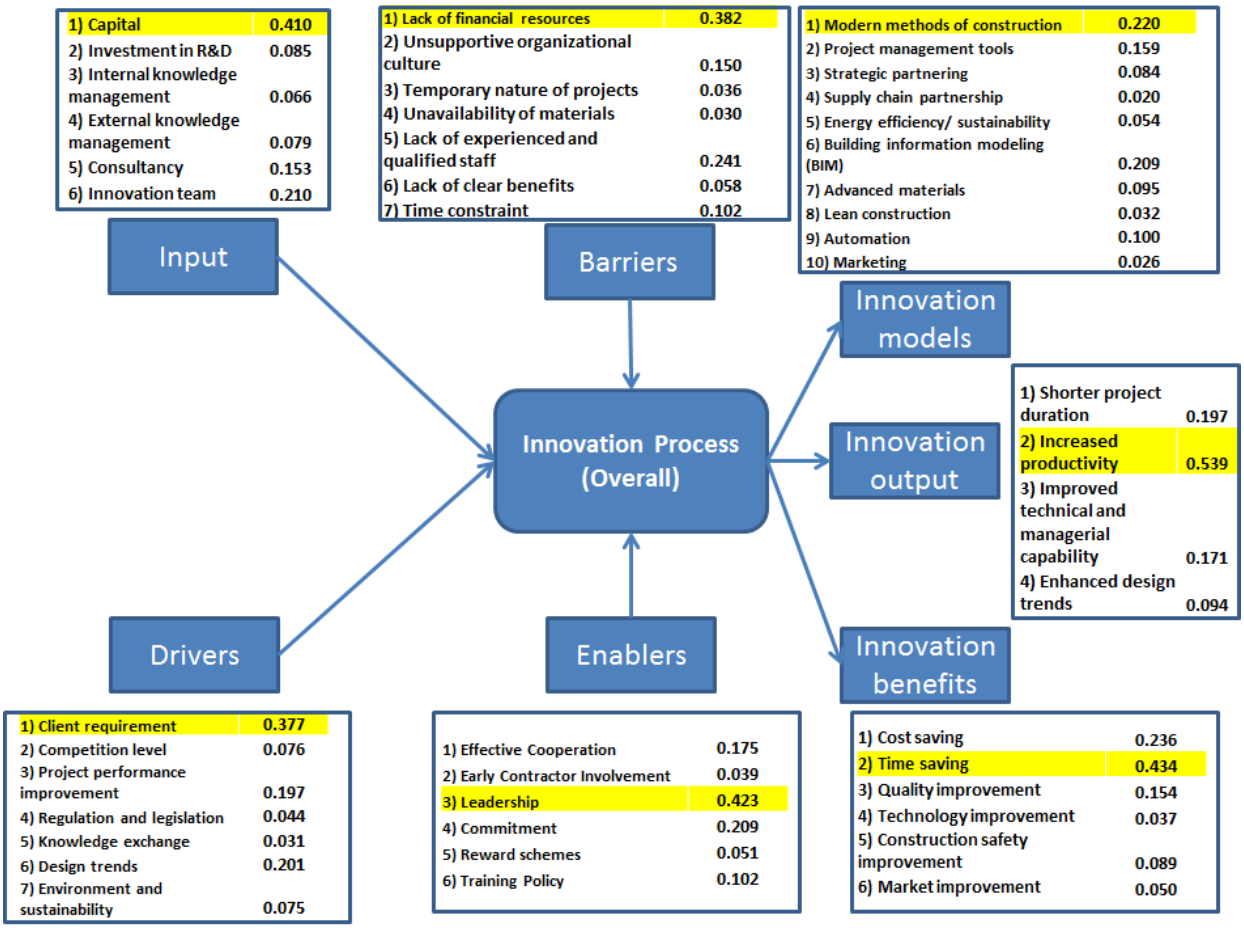

Figure 6. 6 Overall ranking for the innovation process

6.3 Recommendation

Engineering management in the construction industry is not a new topic to be studied and discussed, and it has been applied since the start of construction industry. However, the global market requirements and the worldwide competition need unusual and unique methods to manage the construction projects. Therefore, the topic of innovation in construction industry which was not applied efficiently in the developing countries should now be considered seriously and deeper studies must be done to develop the innovation concept in order to achieve the

competitive dimensions of global market. This paper considered mostly the external factors to initiate the innovation process in construction industry. My recommendation is summarized by having deeper studies of the ability to initiate the input factors and overcome barriers factors.

6.3.1 Contractor

The contractor involvement is only 6.78% which is relatively low compared to other organizations involvement in the innovation process. In previous studies from other regions, the contractor is considered as the highest involved organization in innovation process. Contractors are more interested in innovation and automation due to market competition. However, competition dimensions here in Qatar and Middle East region are related to the financial and resources more than innovation and finding new methods of construction. Based on this project, contractors have to invest more external knowledge management and research and development management to initiate the concept of innovation in their projects in order to be able to successful in complex projects.

6.3.2 Consultant

Consultant is the construction organization that cares about finding solutions, solving technical and operational issues. The involvement of consultant in innovation is relatively high as compared to other organizations and has a percentage of 50.28%. This is because of their involvement in studying and reviewing the modern methods of construction and advanced materials used in construction. The consultant should be involved in innovation management to monitor and control the innovation process.

6.3.3 Project management

The role of project manager in construction projects is mainly to manage all project stakeholders. They are more concerned about the progress and budget of the project. Project management involvement in innovation has a percentage of 26.02% which is good compared to other organizations. The project management should consider innovation process in developing effective coordination between all project parties.

6.3.4 Owner

Owner involvement in innovation is low because owner is not responsible about the method of project execution techniques and project technical issues. However, owner should involve in the innovation project because owner is one of the major driver factors to initiate the innovation process. Having knowledge about innovation from other projects and providing with financial support gives owner the opportunity to successfully achieve complex projects.

6.3.5 Supplier

Supplier has the lowest involvement percentage in innovation process with a score of 3.48%. Their role is not quite flexible and they do not have the tendency to improve the products and the material specifications because they depend on production quantities and purchase orders from the clients. The focus is less towards problem solving or new invention. Suppliers should care more about the department of research and development to continuously monitor the market alternatives and improve their product. Supplier should involve in innovation management to develop advanced materials to solve specific technical issue or provide low cost alternatives.

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APPENDIX A Questionnaire template

PART ONE: GENERAL/PERSONAL INFORMATION

Q1: Years of experience in the construction industry?

Less than 5 years

- 5-10 years
- 10- 15 years
- 15 years or more

Q2: Role of your organization in the current project?

- CONTRACTOR
- CONSULTANT
- OWNER
- PROJECT MANAGEMENT
- SUPPLIER

Q3: Your designation in the organization at the current project?

- SITE ENGINEER
- CONSTRUCTION MANAGER
- PROJECT MANAGER
- OPERATION / GENERAL MANAGER

APPENDIX A Questionnaire template

Q4: Please indicate the impact level of each listed factor on innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines;
(1 – lowest/minor impact 9 – highest impact)

Objectives	Impact level of each factor on innovation process								
1-Cost saving	1	2	3	4	5	6	7	8	9
2-Time saving	1	2	3	4	5	6	7	8	9
3-Quality improvement	1	2	3	4	5	6	7	8	9
4-Technology improvement	1	2	3	4	5	6	7	8	9
5-Construction safety improvement	1	2	3	4	5	6	7	8	9
6-Market improvement	1	2	3	4	5	6	7	8	9

PART TWO: Innovation process components

Q5: Please indicate the impact level of each listed **driver** factor **on** innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines;
(1 – lowest/minor impact 9 – highest impact)

	Impact level of each driver factor on innovation process								
7- Client requirement	1	2	3	4	5	6	7	8	9
8- Competition level	1	2	3	4	5	6	7	8	9
9-Project performance improvement	1	2	3	4	5	6	7	8	9

10- Regulation and legislation	1	2	3	4	5	6	7	8	9
11- Knowledge exchange	1	2	3	4	5	6	7	8	9
12- Design trends	1	2	3	4	5	6	7	8	9
13-Environment and sustainability	1	2	3	4	5	6	7	8	9

Q6: Please indicate the impact level of each listed **barrier** factor **to implement** innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines;
(1 – lowest/minor impact 9 – highest impact)

	Impact level of each barrier factor to implement innovation process								
14- Lack of financial resources	1	2	3	4	5	6	7	8	9
15-Unsupportive organizational culture	1	2	3	4	5	6	7	8	9
16- Temporary nature of projects	1	2	3	4	5	6	7	8	9
17- Unavailability of materials	1	2	3	4	5	6	7	8	9
18- Lack of experienced and qualified staff	1	2	3	4	5	6	7	8	9
19 - Lack of clear benefits	1	2	3	4	5	6	7	8	9
20- Time constraint	1	2	3	4	5	6	7	8	9

APPENDIX A Questionnaire template

Q7: Please indicate the impact level of each listed **input** factor **to initiate** innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines;
(1 – lowest/minor impact 9 – highest impact)

	Impact level of each input factor to initiate innovation process								
21- Capital	1	2	3	4	5	6	7	8	9
22- Investment in R&D	1	2	3	4	5	6	7	8	9
23- Internal knowledge management	1	2	3	4	5	6	7	8	9
24- External knowledge management	1	2	3	4	5	6	7	8	9
25- Consultancy	1	2	3	4	5	6	7	8	9
26- Innovation team	1	2	3	4	5	6	7	8	9

Q8: Please indicate the impact level of each listed **enabler** factor **to implement** innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines;
(1 – lowest/minor impact 9 – highest impact)

	Impact level of each enabler factor on innovation process								
27- Effective cooperation	1	2	3	4	5	6	7	8	9
28- Early contractor involvement	1	2	3	4	5	6	7	8	9
29- Leadership	1	2	3	4	5	6	7	8	9
30- Commitment	1	2	3	4	5	6	7	8	9
31- Reward schemes	1	2	3	4	5	6	7	8	9
32- Training policy	1	2	3	4	5	6	7	8	9

APPENDIX A Questionnaire template

PART THREE: INNOVATION MODELS/ OUTPUT

Q9: Please indicate the impact level of each listed **innovation type to implement** innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines;
(1 – lowest/minor impact 9 – highest impact)

	Impact level of each innovation type to implement innovation process								
33- Modern methods of construction	1	2	3	4	5	6	7	8	9
34- Project management tools	1	2	3	4	5	6	7	8	9
35- Strategic Partnering	1	2	3	4	5	6	7	8	9
36- Supply chain partnership	1	2	3	4	5	6	7	8	9
37- Energy efficiency/ sustainability	1	2	3	4	5	6	7	8	9
38- Building Information Modeling (BIM)	1	2	3	4	5	6	7	8	9
39- Advanced materials	1	2	3	4	5	6	7	8	9
40- Lean construction	1	2	3	4	5	6	7	8	9
41-Automation	1	2	3	4	5	6	7	8	9
42- Marketing	1	2	3	4	5	6	7	8	9

APPENDIX A Questionnaire template

Q10: Please indicate the impact level of each listed **output** factor **on** innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines;
(1 – lowest/minor impact 9 – highest impact)

	Impact level of each output factor on innovation process								
43- Shorter project duration	1	2	3	4	5	6	7	8	9
44- Increased productivity	1	2	3	4	5	6	7	8	9
45- Improved technical and managerial capability	1	2	3	4	5	6	7	8	9
46- Enhanced design trends	1	2	3	4	5	6	7	8	9

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

- Contractors Output:

Role of your organization in the current project?

Answer Options	Response Percent	Response Count
CONTRACTOR	100.0%	53
CONSULTANT	0.0%	0
OWNER	0.0%	0
PROJECT MANAGEMENT	0.0%	0
SUPPLIER	0.0%	0
answered question		53
skipped question		0

Your designation in the organization at the current project?

Answer Options	Response Percent	Response Count
Site Engineer	32.1%	17
Construction manager	20.8%	11
Project Manager	24.5%	13
Operation manager/ General Manager	22.6%	12
answered question		53
skipped question		0

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Your department in the organization at the current project?

Answer Options	Response Percent	Response Count
Contracts/Commercial Dept.	7.7%	4
Construction Dept.	65.4%	34
Technical Design/Engineering Dept.	15.4%	8
Projects Control Dept. (Planning, QA/QC)	9.6%	5
Finance Dept.	1.9%	1
answered question		52
skipped question		1

Your country of work?

Answer Options	Response Percent	Response Count
Qatar	67.3%	35
Middle East & North Africa (Other than Qatar)	32.7%	17
North America	0.0%	0
Europe	0.0%	0
Asia	0.0%	0
answered question		52
skipped question		1

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Please indicate the impact level of each listed factor on innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines;											
Answer Options	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Rating Average**	**Response Count**
1) Cost saving	2	0	1	3	6	6	12	11	12	6.85	53
2) Time saving	1	1	3	1	2	11	8	7	19	7.08	53
3) Quality improvement	1	2	2	4	4	5	9	8	18	6.91	53
4) Technology improvement	1	4	5	8	8	12	7	7	1	5.32	53
5) Construction safety improvement	2	0	2	9	6	10	11	8	5	6.04	53
6) Market improvement	3	3	4	7	8	8	9	5	6	5.55	53
										answered question	53
										skipped question	0

Please indicate the impact level of each listed driver factor on innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines;											
Answer Options	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Rating Average**	**Response Count**
1) Client requirement	0	0	0	2	3	5	9	6	20	7.64	45
2) Competition level	0	1	2	4	4	12	12	6	4	6.31	45
3) Project performance improvement	0	0	2	3	5	3	9	14	9	7.04	45
4) Regulation and legislation	1	3	4	7	3	4	12	3	8	5.91	45
5) Knowledge exchange	2	2	4	9	8	6	7	3	4	5.31	45
6) Design trends	1	0	1	4	8	9	14	5	3	6.20	45
7) Environment and sustainability	1	2	3	3	6	8	10	6	6	6.13	45
										answered question	45
										skipped question	8

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Please indicate the impact level of each listed barrier factor to implement innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines;

Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Lack of financial resources	1	0	0	1	5	3	7	10	18	7.53	45
2) Unsupportive organizational culture	0	1	4	3	5	16	9	4	3	5.98	45
3) Temporary nature of projects	1	2	1	5	10	9	7	6	4	5.89	45
4) Unavailability of materials	2	3	3	2	6	9	4	7	9	6.09	45
5) Lack of experienced and qualified staff	0	0	1	7	8	4	7	10	8	6.58	45
6) Lack of clear benefits	0	3	3	6	5	6	9	9	4	6.02	45
7) Time constraint	0	1	3	5	7	7	9	6	7	6.27	45
										answered question	45
										skipped question	8

Please indicate the impact level of each listed input factor to initiate innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines;

Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Capital	0	1	1	1	4	6	5	7	20	7.47	45
2) Investment in R&D	1	1	2	4	12	6	7	10	2	5.96	45
3) Internal knowledge management	0	1	1	5	8	8	8	10	4	6.33	45
4) External knowledge management	1	1	2	3	7	12	7	11	1	6.09	45
5) Consultancy	0	0	0	5	8	9	9	11	3	6.49	45
6) Innovation team	0	2	2	1	6	9	6	3	16	6.84	45
										answered question	45
										skipped question	8

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Please indicate the impact level of each listed enabler factor to implement innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Effective Cooperation	0	0	1	3	3	3	9	12	14	7.40	45
2) Early Contractor Involvement	0	0	1	7	10	6	6	9	6	6.33	45
3) Leadership	0	0	0	2	1	6	9	7	20	7.73	45
4) Commitment	0	0	1	4	2	7	10	11	10	7.09	45
5) Reward schemes	1	1	2	2	9	8	8	11	3	6.24	45
6) Training Policy	0	3	4	3	4	6	7	11	7	6.36	45
										answered question	45
										skipped question	8

Please indicate the impact level of each listed innovation type to implement innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Modern methods of construction	0	0	1	0	5	3	7	10	19	7.69	45
2) Project management tools	2	9	1	1	4	7	8	7	6	5.67	45
3) Strategic partnering	0	9	1	4	8	4	10	5	4	5.49	45
4) Supply chain partnership	1	8	0	6	6	12	5	2	5	5.31	45
5) Energy efficiency/ sustainability	1	4	3	9	2	11	7	6	2	5.44	45
6) Building information modeling (BIM)	0	1	2	5	8	7	9	7	6	6.29	45
7) Advanced materials	0	0	2	1	10	4	10	12	6	6.76	45
8) Lean construction	0	0	1	9	2	10	10	6	7	6.44	45
9) Automation	0	0	2	5	4	5	7	9	13	6.98	45
10) Marketing	3	6	3	3	4	7	11	4	4	5.40	45
										answered question	45
										skipped question	8

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Please indicate the impact level of each listed output factor on innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Shorter project duration	0	0	0	2	5	6	5	7	20	7.56	45
2) Increased productivity	0	0	0	5	0	1	12	5	22	7.73	45
3) Improved technical and managerial capability	0	0	1	6	8	12	8	4	6	6.24	45
4) Enhanced design trends	0	0	1	4	8	9	10	10	3	6.44	45
										answered question	45
										skipped question	8

- Consultants Output:

Role of your organization in the current project? Answer Options	Response Percent	Response Count
CONTRACTOR	0.0%	0
CONSULTANT	100.0%	15
OWNER	0.0%	0
PROJECT MANAGEMENT	0.0%	0
SUPPLIER	0.0%	0

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Your designation in the organization at the current project?

Answer Options	Response Percent	Response Count
Site Engineer	33.3%	5
Construction manager	6.7%	1
Project Manager	40.0%	6
Operation manager/ General Manager	20.0%	3
answered question		15
skipped question		0

Your department in the organization at the current project?

Answer Options	Response Percent	Response Count
Contracts/Commercial Dept.	0.0%	0
Construction Dept.	26.7%	4
Technical Design/Engineering Dept.	46.7%	7
Projects Control Dept. (Planning, QA/QC)	26.7%	4
Finance Dept.	0.0%	0
answered question		15
skipped question		0

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Your country of work?		
Answer Options	**Response Percent**	**Response Count**
Qatar	80.0%	12
Middle East & North Africa (Other than Qatar)	13.3%	2
North America	6.7%	1
Europe	0.0%	0
Asia	0.0%	0
answered question		15
skipped question		0

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Please indicate the impact level of each listed factor on innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Cost saving	1	0	0	0	1	1	6	3	3	7.00	15
2) Time saving	1	0	0	0	1	1	4	4	4	7.20	15
3) Quality improvement	0	0	1	1	1	0	4	8	0	6.93	15
4) Technology improvement	0	2	0	0	3	2	3	5	0	6.13	15
5) Construction safety improvement	0	1	2	0	2	0	2	5	3	6.60	15
6) Market improvement	1	1	0	1	2	0	3	6	1	6.33	15
									answered question		15
									skipped question		0

Please indicate the impact level of each listed driver factor on innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Client requirement	0	0	0	0	0	1	1	4	7	8.31	13
2) Competition level	0	0	0	0	3	1	6	1	2	6.85	13
3) Project performance improvement	0	1	0	1	0	1	2	5	3	7.15	13
4) Regulation and legislation	0	1	0	1	1	2	3	4	1	6.54	13
5) Knowledge exchange	0	1	1	1	1	0	3	5	1	6.46	13
6) Design trends	0	1	0	0	0	0	4	7	1	7.31	13
7) Environment and sustainability	0	0	0	1	1	1	4	5	1	7.08	13
									answered question		13
									skipped question		2

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Please indicate the impact level of each listed barrier factor to implement innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Lack of financial resources	0	0	0	0	1	0	2	0	10	8.38	13
2) Unsupportive organizational culture	0	0	0	1	2	0	1	6	3	7.38	13
3) Temporary nature of projects	0	0	1	1	2	2	4	2	1	6.31	13
4) Unavailability of materials	1	0	1	0	2	4	0	2	3	6.23	13
5) Lack of experienced and qualified staff	0	0	0	0	1	0	2	5	5	8.00	13
6) Lack of clear benefits	0	0	1	1	1	1	1	8	0	6.85	13
7) Time constraint	0	0	1	0	2	1	0	6	3	7.23	13
										answered question	13
										skipped question	2

Please indicate the impact level of each listed input factor to initiate innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Capital	0	0	1	0	0	0	3	2	7	7.92	13
2) Investment in R&D	0	2	0	1	0	4	1	5	0	6.08	13
3) Internal knowledge management	0	1	1	0	3	1	1	5	1	6.31	13
4) External knowledge management	0	1	1	0	0	4	2	3	2	6.54	13
5) Consultancy	0	1	0	0	0	2	2	5	3	7.31	13
6) Innovation team	0	1	0	1	0	2	0	5	4	7.23	13
										answered question	13
										skipped question	2

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Please indicate the impact level of each listed enabler factor to implement innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines;

Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Effective Cooperation	0	1	0	1	1	1	4	3	2	6.69	13
2) Early Contractor Involvement	1	1	0	0	2	1	4	1	3	6.31	13
3) Leadership	0	1	0	0	0	0	1	5	6	7.92	13
4) Commitment	1	0	0	0	0	1	3	2	6	7.54	13
5) Reward schemes	0	1	1	0	1	0	6	4	0	6.46	13
6) Training Policy	0	0	2	0	2	1	3	2	3	6.62	13
									answered question		13
									skipped question		2

Please indicate the impact level of each listed innovation type to implement innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines;

Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Modern methods of construction	0	0	1	1	1	0	4	1	4	7.00	12
2) Project management tools	1	1	0	0	0	1	1	2	6	7.17	12
3) Strategic partnering	1	0	0	1	0	1	3	2	4	7.00	12
4) Supply chain partnership	1	1	1	0	2	2	2	1	2	5.67	12
5) Energy efficiency/ sustainability	0	0	0	1	2	1	3	3	2	6.92	12
6) Building information modeling (BIM)	0	1	0	0	0	1	3	3	4	7.42	12
7) Advanced materials	0	0	1	1	1	2	2	3	2	6.67	12
8) Lean construction	0	1	2	1	1	0	3	3	1	5.92	12
9) Automation	0	1	0	2	0	1	4	3	1	6.42	12
10) Marketing	1	2	0	1	0	0	3	2	3	6.08	12
									answered question		12
									skipped question		3

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Please indicate the impact level of each listed output factor on innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Shorter project duration	0	1	3	0	0	1	2	2	3	6.17	12
2) Increased productivity	0	0	1	1	1	0	2	2	5	7.25	12
3) Improved technical and managerial capability	1	0	0	0	1	1	1	4	4	7.25	12
4) Enhanced design trends	1	1	0	0	1	0	3	3	3	6.67	12
										answered question	12
										skipped question	3

- Project management Output:

Role of your organization in the current project? Answer Options	Response Percent	Response Count
CONTRACTOR	0.0%	0
CONSULTANT	0.0%	0
OWNER	0.0%	0
PROJECT MANAGEMENT	100.0%	21
SUPPLIER	0.0%	0
answered question		21
skipped question		0

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Your designation in the organization at the current project?		
Answer Options	**Response Percent**	**Response Count**
Site Engineer	4.8%	1
Construction manager	4.8%	1
Project Manager	57.1%	12
Operation manager/ General Manager	33.3%	7

Your department in the organization at the current project?		
Answer Options	**Response Percent**	**Response Count**
Contracts/Commercial Dept.	9.5%	2
Construction Dept.	38.1%	8
Technical Design/Engineering Dept.	38.1%	8
Projects Control Dept. (Planning, QA/QC)	14.3%	3
Finance Dept.	0.0%	0
	answered question	21
	skipped question	0

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Your country of work?

Answer Options	Response Percent	Response Count
Qatar	76.2%	16
Middle East & North Africa (Other than Qatar)	19.0%	4
North America	4.8%	1
Europe	0.0%	0
Asia	0.0%	0
	answered question	21
	skipped question	0

Please indicate the impact level of each listed factor on innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines;

Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Cost saving	1	1	0	0	2	4	4	1	8	6.90	21
2) Time saving	0	1	0	0	4	2	3	4	7	7.14	21
3) Quality improvement	0	0	1	3	4	1	7	1	4	6.38	21
4) Technology improvement	0	0	2	2	7	3	6	0	1	5.62	21
5) Construction safety improvement	0	0	1	1	6	4	4	4	1	6.19	21
6) Market improvement	0	1	0	4	4	5	3	3	1	5.81	21
									answered question		21
									skipped question		0

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Please indicate the impact level of each listed driver factor on innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Client requirement	0	0	1	1	3	1	2	3	8	7.26	19
2) Competition level	0	1	0	2	4	2	5	4	1	6.21	19
3) Project performance improvement	0	0	0	1	3	3	2	5	5	7.16	19
4) Regulation and legislation	0	1	1	4	2	3	2	3	3	6.00	19
5) Knowledge exchange	0	0	1	3	4	7	1	0	3	5.84	19
6) Design trends	0	0	0	1	3	8	4	3	0	6.26	19
7) Environment and sustainability	1	0	1	2	3	4	5	2	1	5.84	19
									answered question		19
									skipped question		2

Please indicate the impact level of each listed barrier factor to implement innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Lack of financial resources	1	1	0	1	1	1	1	2	11	7.37	19
2) Unsupportive organizational culture	0	0	1	0	2	3	5	4	4	7.05	19
3) Temporary nature of projects	0	0	1	2	6	3	6	1	0	5.74	19
4) Unavailability of materials	0	1	1	3	5	2	3	2	2	5.74	19
5) Lack of experienced and qualified staff	0	0	1	1	1	4	0	7	5	7.21	19
6) Lack of clear benefits	1	0	1	2	3	3	5	3	1	5.95	19
7) Time constraint	0	0	2	1	2	2	5	4	3	6.63	19
									answered question		19
									skipped question		2

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Please indicate the impact level of each listed input factor to initiate innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Capital	0	0	0	1	2	2	3	4	7	7.47	19
2) Investment in R&D	0	0	0	4	3	2	4	2	4	6.47	19
3) Internal knowledge management	0	0	1	3	4	1	4	4	2	6.26	19
4) External knowledge management	0	0	0	3	6	3	2	4	1	6.05	19
5) Consultancy	0	1	0	3	5	3	2	2	3	6.00	19
6) Innovation team	0	0	0	2	3	0	2	7	5	7.26	19
								answered question			19
								skipped question			2

Please indicate the impact level of each listed enabler factor to implement innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Effective Cooperation	1	0	0	1	1	0	5	3	8	7.42	19
2) Early Contractor Involvement	0	1	0	2	3	3	4	2	4	6.47	19
3) Leadership	0	0	1	1	0	1	1	4	11	7.95	19
4) Commitment	0	0	0	2	1	2	2	4	8	7.53	19
5) Reward schemes	0	0	1	1	2	5	4	2	4	6.68	19
6) Training Policy	0	0	1	1	3	2	3	3	6	7.00	19
								answered question			19
								skipped question			2

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Please indicate the impact level of each listed innovation type to implement innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Modern methods of construction	0	0	0	0	2	0	3	6	6	7.82	17
2) Project management tools	0	0	0	1	2	2	4	6	2	7.06	17
3) Strategic partnering	0	0	0	0	4	2	5	5	1	6.82	17
4) Supply chain partnership	0	0	0	2	2	5	3	4	1	6.47	17
5) Energy efficiency/ sustainability	0	0	1	1	3	3	2	5	2	6.59	17
6) Building information modeling (BIM)	0	1	0	0	2	3	2	4	5	7.12	17
7) Advanced materials	1	0	0	0	1	3	3	5	4	7.12	17
8) Lean construction	0	0	0	0	6	2	4	2	3	6.65	17
9) Automation	0	0	0	1	0	3	4	6	3	7.35	17
10) Marketing	0	0	1	1	3	2	6	3	1	6.41	17
										answered question	17
										skipped question	4

Please indicate the impact level of each listed output factor on innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Shorter project duration	0	0	1	0	2	0	2	5	7	7.65	17
2) Increased productivity	0	0	1	0	2	1	1	3	9	7.71	17
3) Improved technical and managerial capability	0	0	0	2	4	3	2	4	2	6.47	17
4) Enhanced design trends	0	0	0	1	2	4	4	3	3	6.88	17

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

- Owner Output:

Role of your organization in the current project?		
Answer Options	**Response Percent**	**Response Count**
CONTRACTOR	0.0%	0
CONSULTANT	0.0%	0
OWNER	100.0%	17
PROJECT MANAGEMENT	0.0%	0
SUPPLIER	0.0%	0
answered question		17
skipped question		0

Your designation in the organization at the current project?		
Answer Options	**Response Percent**	**Response Count**
Site Engineer	0.0%	0
Construction manager	0.0%	0
Project Manager	82.4%	14
Operation manager/ General Manager	17.6%	3
answered question		17
skipped question		0

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Your department in the organization at the current project?

Answer Options	Response Percent	Response Count
Contracts/Commercial Dept.	5.9%	1
Construction Dept.	29.4%	5
Technical Design/Engineering Dept.	58.8%	10
Projects Control Dept. (Planning, QA/QC)	5.9%	1
Finance Dept.	0.0%	0
answered question		17
skipped question		0

Your country of work?

Answer Options	Response Percent	Response Count
Qatar	76.5%	13
Middle East & North Africa (Other than Qatar)	23.5%	4
North America	0.0%	0
Europe	0.0%	0
Asia	0.0%	0
answered question		17
skipped question		0

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Please indicate the impact level of each listed factor on innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Cost saving	0	0	0	0	2	1	6	6	2	7.29	17
2) Time saving	0	0	0	0	1	2	4	5	5	7.65	17
3) Quality improvement	0	0	0	1	1	3	4	5	3	7.18	17
4) Technology improvement	0	0	0	2	3	4	4	2	2	6.41	17
5) Construction safety improvement	0	0	0	1	1	6	6	1	2	6.65	17
6) Market improvement	0	0	0	3	2	5	4	2	1	6.18	17
									answered question		17
									skipped question		0

Please indicate the impact level of each listed driver factor on innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Client requirement	0	1	1	0	2	0	1	6	5	7.19	16
2) Competition level	0	0	0	3	2	5	3	3	0	6.06	16
3) Project performance improvement	0	0	1	0	2	5	1	4	3	6.81	16
4) Regulation and legislation	0	0	0	6	1	1	4	2	2	6.06	16
5) Knowledge exchange	0	0	0	3	3	6	2	2	0	5.81	16
6) Design trends	0	0	0	1	3	5	2	3	2	6.56	16
7) Environment and sustainability	0	0	0	2	1	5	7	1	0	6.25	16
									answered question		16
									skipped question		1

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Please indicate the impact level of each listed barrier factor to implement innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Lack of financial resources	0	0	1	1	0	2	1	4	7	7.56	16
2) Unsupportive organizational culture	0	0	0	4	1	1	4	4	2	6.56	16
3) Temporary nature of projects	0	0	1	1	4	6	2	2	0	5.81	16
4) Unavailability of materials	0	0	0	4	1	4	5	1	1	6.06	16
5) Lack of experienced and qualified staff	0	0	0	1	1	4	5	2	3	6.94	16
6) Lack of clear benefits	0	0	1	2	3	4	2	2	2	6.13	16
7) Time constraint	0	0	0	3	1	4	2	4	2	6.56	16
									answered question		16
									skipped question		1

Please indicate the impact level of each listed input factor to initiate innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Capital	0	0	0	1	3	2	2	3	5	7.13	16
2) Investment in R&D	0	0	0	2	3	5	1	4	1	6.31	16
3) Internal knowledge management	0	0	0	1	6	2	6	1	0	6.00	16
4) External knowledge management	0	0	0	1	4	6	3	2	0	6.06	16
5) Consultancy	0	0	0	3	3	4	4	1	1	6.00	16
6) Innovation team	0	0	1	1	3	3	1	3	4	6.69	16
									answered question		16
									skipped question		1

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Please indicate the impact level of each listed enabler factor to implement innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Effective Cooperation	0	0	0	1	2	2	4	7	0	6.88	16
2) Early Contractor Involvement	0	0	0	1	3	5	3	4	0	6.38	16
3) Leadership	0	0	0	1	1	1	4	5	4	7.44	16
4) Commitment	0	0	0	2	1	4	3	3	3	6.81	16
5) Reward schemes	0	0	0	1	4	6	2	3	0	6.13	16
6) Training Policy	0	0	0	1	1	5	2	6	1	6.88	16

Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Modern methods of construction	0	0	0	0	2	0	3	7	3	7.60	15
2) Project management tools	0	0	0	0	3	1	3	4	4	7.33	15
3) Strategic partnering	0	0	0	1	2	4	3	5	0	6.60	15
4) Supply chain partnership	0	0	0	0	5	3	4	2	1	6.40	15
5) Energy efficiency/ sustainability	0	0	0	1	2	7	3	2	0	6.20	15
6) Building information modeling (BIM)	0	0	0	2	3	2	2	2	4	6.73	15
7) Advanced materials	0	0	0	0	4	1	4	4	2	6.93	15
8) Lean construction	0	0	1	1	4	4	4	0	1	5.87	15
9) Automation	0	1	0	1	1	2	6	2	2	6.60	15
10) Marketing	0	0	0	1	5	1	4	2	2	6.47	15
									answered question		15
									skipped question		2

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Please indicate the impact level of each listed output factor on innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Shorter project duration	0	0	0	0	3	0	4	3	5	7.47	15
2) Increased productivity	0	0	0	0	2	3	3	3	4	7.27	15
3) Improved technical and managerial capability	0	0	0	0	0	7	2	4	2	7.07	15
4) Enhanced design trends	0	0	0	0	2	2	4	6	1	7.13	15
										answered question	15
										skipped question	2

- Suppliers Output:

Role of your organization in the current project? Answer Options	Response Percent	Response Count
CONTRACTOR	0.0%	0
CONSULTANT	0.0%	0
OWNER	0.0%	0
PROJECT MANAGEMENT	0.0%	0
SUPPLIER	100.0%	15

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Your designation in the organization at the current project?

Answer Options	Response Percent	Response Count
Site Engineer	13.3%	2
Construction manager	13.3%	2
Project Manager	33.3%	5
Operation manager/ General Manager	40.0%	6
answered question		15
skipped question		0

Your department in the organization at the current project?

Answer Options	Response Percent	Response Count
Contracts/Commercial Dept.	26.7%	4
Construction Dept.	26.7%	4
Technical Design/Engineering Dept.	40.0%	6
Projects Control Dept. (Planning, QA/QC)	6.7%	1
Finance Dept.	0.0%	0
answered question		15
skipped question		0

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Your country of work?		
Answer Options	**Response Percent**	**Response Count**
Qatar	60.0%	9
Middle East & North Africa (Other than Qatar)	26.7%	4
North America	6.7%	1
Europe	6.7%	1
Asia	0.0%	0
answered question		15
skipped question		0

Please indicate the impact level of each listed factor on innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines;											
Answer Options	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Rating Average**	**Response Count**
1) Cost saving	0	1	1	0	1	5	3	2	2	6.33	15
2) Time saving	0	1	1	0	0	1	2	1	9	7.60	15
3) Quality improvement	0	0	0	1	1	1	4	4	4	7.40	15
4) Technology improvement	0	1	0	1	3	3	4	1	2	6.20	15
5) Construction safety improvement	0	0	0	2	2	4	4	0	3	6.47	15
6) Market improvement	1	1	0	3	1	2	3	1	3	5.87	15

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Please indicate the impact level of each listed driver factor on innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Client requirement	0	0	1	0	1	1	1	2	7	7.69	13
2) Competition level	0	0	1	2	4	0	4	1	1	5.85	13
3) Project performance improvement	0	0	2	0	1	0	5	2	3	6.85	13
4) Regulation and legislation	0	4	3	3	2	0	0	0	1	3.69	13
5) Knowledge exchange	0	1	3	3	2	0	1	1	2	5.08	13
6) Design trends	0	0	1	0	1	2	2	6	1	7.00	13
7) Environment and sustainability	0	1	0	2	1	3	2	1	3	6.31	13
									answered question		13
									skipped question		2

Please indicate the impact level of each listed barrier factor to implement innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Lack of financial resources	0	1	1	0	0	1	2	2	6	7.31	13
2) Unsupportive organizational culture	0	1	1	1	4	1	3	1	1	5.62	13
3) Temporary nature of projects	1	3	0	2	2	4	0	1	0	4.38	13
4) Unavailability of materials	2	3	0	2	3	1	1	0	1	4.08	13
5) Lack of experienced and qualified staff	1	0	2	2	2	3	2	0	1	5.08	13
6) Lack of clear benefits	2	1	2	4	1	2	1	0	0	3.85	13
7) Time constraint	0	1	0	3	3	1	3	2	0	5.54	13
									answered question		13
									skipped question		2

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Please indicate the impact level of each listed input factor to initiate innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines;

Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Capital	0	1	2	0	0	1	1	2	6	7.00	13
2) Investment in R&D	0	1	1	0	5	2	1	1	2	5.77	13
3) Internal knowledge management	0	0	3	2	2	2	2	1	1	5.38	13
4) External knowledge management	0	0	1	2	2	4	2	2	0	5.77	13
5) Consultancy	1	0	2	2	4	1	1	1	1	5.00	13
6) Innovation team	0	0	0	1	1	0	1	5	5	7.77	13
										answered question	13
										skipped question	2

Please indicate the impact level of each listed enabler factor to implement innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines;

Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Effective Cooperation	0	0	2	1	0	0	5	2	3	6.77	13
2) Early Contractor Involvement	1	1	1	0	4	1	1	1	3	5.69	13
3) Leadership	0	0	0	1	0	3	0	2	7	7.77	13
4) Commitment	0	1	0	2	1	3	2	2	2	6.23	13
5) Reward schemes	0	1	1	2	0	1	5	3	0	6.00	13
6) Training Policy	0	0	0	2	1	0	3	2	5	7.31	13
										answered question	13
										skipped question	2

APPENDIX B : Contractors, Consultants, Project Management, Owner, and Suppliers survey results reports

Please indicate the impact level of each listed innovation type to implement innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Modern methods of construction	1	0	0	0	1	0	1	2	8	7.77	13
2) Project management tools	1	2	2	1	1	1	0	1	4	5.38	13
3) Strategic partnering	0	1	3	1	2	2	0	0	4	5.62	13
4) Supply chain partnership	0	0	2	1	3	3	2	0	2	5.77	13
5) Energy efficiency/ sustainability	0	1	0	0	6	1	1	2	2	6.08	13
6) Building information modeling (BIM)	0	0	1	2	0	1	3	2	4	6.92	13
7) Advanced materials	0	0	1	0	1	0	3	1	7	7.69	13
8) Lean construction	0	0	3	1	2	3	2	1	1	5.54	13
9) Automation	0	0	1	1	1	1	4	1	4	6.92	13
10) Marketing	0	1	1	1	4	2	2	0	2	5.62	13

Please indicate the impact level of each listed output factor on innovation process in construction industry? (Please mark your response with (✓) from 1 to 9, based on the following guidelines; Answer Options	1	2	3	4	5	6	7	8	9	Rating Average	Response Count
1) Shorter project duration	0	0	1	0	1	0	3	3	5	7.54	13
2) Increased productivity	0	0	1	0	0	0	2	3	7	8.00	13
3) Improved technical and managerial capability	0	0	2	0	4	1	1	3	2	6.23	13
4) Enhanced design trends	0	0	1	1	2	5	2	0	2	6.08	13
									answered question		13
									skipped question		2

APPENDIX C: Construction organizations scoring matrices of innovation factors

	Consultant					
	Cost saving	Time saving	Quality improvement	Technology improvement	Construction safety	Market improvement
1) Cost saving	1	0.5	2	7	3	5
2) Time saving	2	1	3	9	5	7
3) Quality improvement	0.5	0.333	1	5	2	3
4) Technology improvement	0.143	0.111	0.2	1	0.333	0.5
5) Construction safety improvement	0.333	0.2	0.5	3	1	2
6) Market improvement	0.2	0.143	0.333	2	0.5	1

APPENDIX C: Construction organizations scoring matrices of innovation factors

	Consultant						
	Client requirement	Competition level	Project performance level	Regulation and legislation	Knowledge exchange	Design trends	Environment and sustainability
1) Client requirement	1	7	3	8	9	2	5
2) Competition level	0.143	1	0.333	2	3	0.2	0.5
3) Project performance improvement	0.333	3	1	5	7	0.5	2
4) Regulation and legislation	0.125	0.5	0.2	1	2	0.143	0.333
5) Knowledge exchange	0.111	0.333	0.143	0.5	1	0.125	0.2
6) Design trends	0.5	5	2	7	8	1	3
7) Environment and sustainability	0.2	2	0.5	3	5	0.333	1

APPENDIX C: Construction organizations scoring matrices of innovation factors

	Consultant						
	Lack of financial resources	Unsupportive organizational culture	Temporary nature of projects	Unavailability of materials	Lack of experienced and qualified	Lack of clear benefits	Time constraint
1) Lack of financial resources	1	3	8	9	2	7	5
2) Unsupportive organizational culture	0.333	1	5	7	0.5	3	2
3) Temporary nature of projects	0.125	0.2	1	2	0.143	0.5	0.333
4) Unavailability of materials	0.111	0.143	0.5	1	0.125	0.333	0.2
5) Lack of experienced and qualified staff	0.5	2	7	8	1	5	3
6) Lack of clear benefits	0.143	0.333	2	3	0.167	1	0.5
7) Time constraint	0.2	0.5	3	5	0.333	2	1

APPENDIX C: Construction organizations scoring matrices of innovation factors

Consultant						
	Capital	Investment in R&D	Internal knowledge management	External knowledge management	Consultancy	Innovation team
1) Capital	1	9	7	5	2	3
2) Investment in R&D	0.111	1	0.5	0.2	0.143	0.2
3) Internal knowledge management	0.143	2	1	0.5	0.2	0.333
4) External knowledge management	0.2	3	2	1	0.333	0.5
5) Consultancy	0.5	7	5	3	1	2
6)Innovation team	0.333	5	3	2	0.5	1

Consultant						
	Effective Cooperation	Early Contractor Involvement	Leadership	Commitment	Reward schemes	Training Policy
1) Effective Cooperation	1	5	0.333	0.5	3	2
2) Early Contractor Involvement	0.2	1	0.111	0.143	0.5	0.333
3) Leadership	3	9	1	2	7	5
4) Commitment	2	7	0.5	1	5	3
5) Reward schemes	0.333	2	0.143	0.2	1	0.5
6) Training Policy	0.5	3	0.2	0.333	2	1

APPENDIX C: Construction organizations scoring matrices of innovation factors

	Consultant									
	Modern methods of construction	Project management tools	Strategic partnering	Supply chain partnership	Energy efficiency/ sustainability	Building information modeling (BIM)	Advanced materials	Lean construction	Automation	Marketing
1) Modern methods of construction	1	0.5	2	8	3	0.333	4	7	5	6
2) Project management tools	2	1	3	9	4	0.5	5	8	6	7
3) Strategic partnering	0.5	0.333	1	7	2	0.25	3	6	4	5
4) Supply chain partnership	0.125	0.111	0.143	1	0.167	0.1	0.2	0.5	0.25	0.333
5) Energy efficiency/ sustainability	0.333	0.25	0.5	6	1	0.2	2	5	3	4
6) Building information modeling (BIM)	3	2	4	10	5	1	6	9	7	8
7) Advanced materials	0.25	0.2	0.333	5	0.5	0.167	1	4	2	3
8) Lean construction	0.143	0.125	0.167	2	0.2	0.111	0.25	1	0.333	0.5
9) Automation	0.2	0.167	0.25	4	0.333	0.143	0.5	3	1	2
10) Marketing	0.167	0.143	0.2	3	0.25	0.125	0.333	2	0.5	1

APPENDIX C: Construction organizations scoring matrices of innovation factors

	Consultant			
	Short project duration	Increased productivity	Improved technical and managerial	Enhanced design trends
1) Shorter project duration	1	0.111	0.143	0.333
2) Increased productivity	9	1	3	7
3) Improved technical and managerial capability	7	0.333	1	5
4) Enhanced design trends	3	0.143	0.2	1

	Project management					
	Cost saving	Time saving	Quality improvement	Technology improvement	Construction safety	Market improvement
1) Cost saving	1	0.5	2	7	3	5
2) Time saving	2	1	3	9	5	7
3) Quality improvement	0.5	0.333	1	5	2	3
4) Technology improvement	0.143	0.111	0.2	1	0.333	0.5
5) Construction safety improvement	0.333	0.2	0.5	3	1	2
6) Market improvement	0.2	0.143	0.333	2	0.5	1

APPENDIX C: Construction organizations scoring matrices of innovation factors

	Project management						
	Client requirement	Competition level	Project performance level	Regulation and legislation	Knowledge exchange	Design trends	Environment and sustainability
1) Client requirement	1	5	2	7	8	3	9
2) Competition level	0.2	1	0.333	2	3	0.5	5
3) Project performance improvement	0.5	3	1	5	7	2	8
4) Regulation and legislation	0.143	0.5	0.2	1	2	0.333	3
5) Knowledge exchange	0.125	0.333	0.286	0.5	1	0.2	2
6) Design trends	0.333	2	0.5	3	5	1	7
7) Environment and sustainability	0.111	0.2	0.125	0.333	0.5	0.143	1

	Project management						
	Lack of financial resources	Unsupportive organizational culture	Temporary nature of projects	Unavailability of materials	Lack of experienced and qualified	Lack of clear benefits	Time constraint
1) Lack of financial resources	1	3	8	9	2	7	5
2) Unsupportive organizational culture	0.333	1	5	7	0.5	3	2
3) Temporary nature of projects	0.125	0.2	1	2	0.143	0.5	0.333
4) Unavailability of materials	0.111	0.143	0.5	1	0.125	0.333	0.2
5) Lack of experienced and qualified staff	0.5	2	7	8	1	5	3
6) Lack of clear benefits	0.143	0.333	2	3	0.200	1	0.5
7) Time constraint	0.2	0.5	3	5	0.333	2	1

APPENDIX C: Construction organizations scoring matrices of innovation factors

	Project management					
	Capital	Investment in R&D	Internal knowledge management	External knowledge management	Consultancy	Innovation team
1) Capital	1	3	5	7	9	2
2) Investment in R&D	0.333	1	2	3	5	0.5
3) Internal knowledge management	0.2	0.5	1	2	3	0.333
4) External knowledge management	0.143	0.333	0.5	1	2	0.2
5) Consultancy	0.111	0.2	0.333	0.5	1	0.143
6) Innovation team	0.5	2	3	5	7	1

	Project management					
	Effective Cooperation	Early Contractor Involvement	Leadership	Commitment	Reward schemes	Training Policy
1) Effective Cooperation	1	5	0.333	0.5	3	2
2) Early Contractor Involvement	0.2	1	0.111	0.143	0.5	0.333
3) Leadership	3	9	1	2	7	5
4) Commitment	2	7	0.5	1	5	3
5) Reward schemes	0.333	2	0.143	0.2	1	0.5
6) Training Policy	0.5	3	0.2	0.333	2	1

APPENDIX C: Construction organizations scoring matrices of innovation factors

	Project management									
	Modern methods of construction	Project management tools	Strategic partnering	Supply chain partnership	Energy efficiency/ sustainability	Building information modeling (BIM)	Advanced materials	Lean construction	Automation	Marketing
1) Modern methods of construction	1	5	6	9	8	3	4	7	2	10
2) Project management tools	0.2	1	2	5	4	0.333	0.5	3	0.25	6
3) Strategic partnering	0.167	0.5	1	4	3	0.25	0.333	2	0.2	5
4) Supply chain partnership	0.111	0.2	0.25	1	0.5	0.143	0.167	0.333	0.125	2
5) Energy efficiency/ sustainability	0.125	0.25	0.333	2	1	0.167	0.200	0.5	0.143	3
6) Building information modeling (BIM)	0.333	3	4	7	6	1	2	5	0.5	8
7) Advanced materials	0.25	2	3	6	5	0.5	1	4	0.333	7
8) Lean construction	0.143	0.333	0.5	3	2	0.2	0.25	1	0.167	4
9) Automation	0.5	4	5	8	7	2	3	6	1	9
10) Marketing	0.1	0.167	0.2	0.5	0.333	0.125	0.143	0.25	0.111	1

APPENDIX C: Construction organizations scoring matrices of innovation factors

	Project management			
	Short project duration	Increased productivity	Improved technical and managerial	Enhanced design trends
1) Shorter project duration	1	0.333	7	3
2) Increased productivity	3	1	9	7
3) Improved technical and managerial capability	0.143	0.111	1	0.333
4) Enhanced design trends	0.333	0.143	3	1

	Owner					
	Cost saving	Time saving	Quality improvement	Technology improvement	Construction safety	Market improvement
1) Cost saving	1	0.5	2	5	3	7
2) Time saving	2	1	3	7	5	9
3) Quality improvement	0.5	0.333	1	3	2	5
4) Technology improvement	0.2	0.143	0.333	1	0.5	2
5) Construction safety improvement	0.3333	0.2	0.5	2	1	3
6) Market improvement	0.1429	0.111	0.2	0.5	0.333	1

APPENDIX C: Construction organizations scoring matrices of innovation factors

	Owner						
	Client requirement	Competition level	Project performance level	Regulation and legislation	Knowledge exchange	Design trends	Environment and sustainability
1) Client requirement	1	7	2	8	9	3	5
2) Competition level	0.143	1	0.2	2	3	0.333	0.5
3) Project performance improvement	0.5	5	1	7	8	2	3
4) Regulation and legislation	0.125	0.5	0.143	1	2	0.2	0.333
5) Knowledge exchange	0.111	0.333	0.125	0.5	1	0.143	0.2
6) Design trends	0.333	3	0.5	5	7	1	2
7) Environment and sustainability	0.200	2	0.333	3	5	0.5	1

APPENDIX C: Construction organizations scoring matrices of innovation factors

	Owner						
	Lack of financial resources	Unsupportive organizational culture	Temporary nature of projects	Unavailability of materials	Lack of experienced and qualified	Lack of clear benefits	Time constraint
1) Lack of financial resources	1	3	9	8	2	7	5
2) Unsupportive organizational culture	0.333	1	7	5	0.5	3	2
3) Temporary nature of projects	0.111	0.143	1	0.5	0.125	0.333	0.2
4) Unavailability of materials	0.125	0.2	2	1	0.143	0.5	0.333
5) Lack of experienced and qualified staff	0.5	2	8	7	1	5	3
6) Lack of clear benefits	0.143	0.333	3	2	0.2	1	0.5
7) Time constraint	0.2	0.5	5	3	0.333	2	1

APPENDIX C: Construction organizations scoring matrices of innovation factors

	Owner					
	Capital	Investment in R&D	Internal knowledge management	External knowledge management	Consultancy	Innovation team
1) Capital	1	3	7	5	9	2
2) Investment in R&D	0.333	1	3	2	5	0.5
3) Internal knowledge management	0.143	0.333	1	0.5	2	0.2
4) External knowledge management	0.2	0.5	2	1	3	0.333
5) Consultancy	0.111	0.2	0.5	0.333	1	0.143
6) Innovation team	0.5	2	5	3	7	1

	Owner			
	Short project duration	Increased productivity	Improved technical and managerial	Enhanced design trends
1) Shorter project duration	1	3	9	7
2) Increased productivity	0.333	1	7	3
3) Improved technical and managerial capability	0.111	0.143	1	0.333
4) Enhanced design trends	0.143	0.333	3	1

APPENDIX C: Construction organizations scoring matrices of innovation factors

	Owner									
	Modern methods of construction	Project management tools	Strategic partnering	Supply chain partnership	Energy efficiency/ sustainability	Building information modeling (BIM)	Advanced materials	Lean construction	Automation	Marketing
1) Modern methods of construction	1	2	5	8	9	4	3	10	6	7
2) Project management tools	0.5	1	4	7	8	3	2	9	5	6
3) Strategic partnering	0.2	0.25	1	4	5	0.5	0.333	6	2	3
4) Supply chain partnership	0.125	0.143	0.25	1	2	0.2	0.167	3	0.333	0.5
5) Energy efficiency/ sustainability	0.111	0.125	0.2	0.5	1	0.167	0.143	2	0.25	0.333
6) Building information modeling (BIM)	0.25	0.333	2	5	6	1	0.5	7	3	4
7) Advanced materials	0.333	0.5	3	6	7	2	1	8	4	5
8) Lean construction	0.1	0.111	0.167	0.333	0.5	0.143	0.125	1	0.2	0.25
9) Automation	0.167	0.2	0.5	3	4	0.333	0.25	5	1	2
10) Marketing	0.143	0.167	0.333	2	3	0.25	0.2	4	0.5	1

APPENDIX C: Construction organizations scoring matrices of innovation factors

	Supplier					
	Cost saving	Time saving	Quality improvement	Technology improvement	Construction safety	Market improvement
1) Cost saving	1	0.2	0.333	2	0.5	3
2) Time saving	5	1	2	7	3	9
3) Quality improvement	3	0.5	1	5	2	7
4) Technology improvement	0.5	0.143	0.2	1	0.333	2
5) Construction safety improvement	2	0.333	0.5	3	1	5
6) Market improvement	0.333	0.111	0.143	0.5	0.2	1

	Supplier						
	Client requirement	Competition level	Project performance level	Regulation and legislation	Knowledge exchange	Design trends	Environment and sustainability
1) Client requirement	1	7	3	9	8	2	5
2) Competition level	0.143	1	0.333	3	2	0.2	0.5
3) Project performance improvement	0.333	3	1	7	5	0.5	2
4) Regulation and legislation	0.111	0.333	0.143	1	0.5	0.125	0.2
5) Knowledge exchange	0.125	0.5	0.2	2	1	0.143	0.333
6) Design trends	0.5	5	2	8	7	1	3
7) Environment and sustainability	0.2	2	0.5	5	3	0.333	1

APPENDIX C: Construction organizations scoring matrices of innovation factors

	Supplier						
	Lack of financial resources	Unsupportive organizational culture	Temporary nature of projects	Unavailability of materials	Lack of experienced and qualified	Lack of clear benefits	Time constraint
1) Lack of financial resources	1	2	7	8	5	9	3
2) Unsupportive organizational culture	0.5	1	5	7	3	8	2
3) Temporary nature of projects	0.143	0.2	1	2	0.5	3	0.333
4) Unavailability of materials	0.125	0.143	0.5	1	0.333	2	0.2
5) Lack of experienced and qualified staff	0.2	0.333	2	3	1	5	0.5
6) Lack of clear benefits	0.111	0.125	0.333	0.5	0.2	1	0.143
7) Time constraint	0.333	0.5	3	5	2	7	1

	Supplier					
	Effective Cooperation	Early Contractor Involvement	Leadership	Commitment	Reward schemes	Training Policy
1) Effective Cooperation	1	5	0.333	2	3	0.5
2) Early Contractor Involvement	0.2	1	0.111	0.333	0.5	0.143
3) Leadership	3	9	1	5	7	2
4) Commitment	0.5	3	0.2	1	2	0.333
5) Reward schemes	0.333	2	0.143	0.5	1	0.2
6) Training Policy	2	7	0.5	3	5	1

APPENDIX C: Construction organizations scoring matrices of innovation factors

	Supplier									
	Mdern methods of construction	Project management tools	Strategic partnering	Supply chain partnership	Energy efficiency/ sustainability	Building information modeling (BIM)	Advanced materials	Lean construction	Automation	Marketing
1) Modern methods of construction	1	10	7	6	5	3	2	9	4	8
2) Project management tools	0.1	1	0.25	0.2	0.167	0.125	0.111	0.5	0.143	0.333
3) Strategic partnering	0.143	4	1	0.5	0.333	0.2	0.167	3	0.25	2
4) Supply chain partnership	0.167	5	2	1	0.5	0.25	0.2	4	0.333	3
5) Energy efficiency/ sustainability	0.2	6	3	2	1	0.333	0.25	5	0.5	4
6) Building information modeling (BIM)	0.333	8	5	4	3	1	0.5	7	2	6
7) Advanced materials	0.5	9	6	5	4	2	1	8	3	7
8) Lean construction	0.111	2	0.333	0.25	0.2	0.143	0.125	1	0.167	0.5
9) Automation	0.25	7	4	3	2	0.5	0.333	6	1	5
10) Marketing	0.125	3	0.5	0.333	0.25	0.167	0.143	2	0.2	1

APPENDIX C: Construction organizations scoring matrices of innovation factors

	Supplier			
	Short project duration	Increased productivity	Improved technical and managerial	Enhanced design trends
1) Shorter project duration	1	0.333	3	7
2) Increased productivity	3	1	7	9
3) Improved technical and managerial capability	0.333	0.143	1	3
4) Enhanced design trends	0.143	0.111	0.333	1

APPENDIX D: Normalized matrices of innovation factors

	Consultant (Normalized)					
	Cost saving	Time saving	Quality improvement	Technology improvement	Construction safety	Market improvement
1) Cost saving	0.239	0.219	0.284	0.259	0.254	0.270
2) Time saving	0.479	0.437	0.427	0.333	0.423	0.378
3) Quality improvement	0.120	0.146	0.142	0.185	0.169	0.162
4) Technology improvement	0.034	0.049	0.028	0.037	0.028	0.027
5) Construction safety improvement	0.080	0.087	0.071	0.111	0.085	0.108
6) Market improvement	0.048	0.062	0.047	0.074	0.042	0.054

	Consultant (Normalized)						
	Client requirement	Competition level	Project performance level	Regulation and legislation	Knowledge exchange	Design trends	Environment and sustainability
1) Client requirement	0.415	0.372	0.418	0.302	0.257	0.465	0.416
2) Competition level	0.059	0.053	0.046	0.075	0.086	0.046	0.042
3) Project performance improvement	0.138	0.159	0.139	0.189	0.200	0.116	0.166
4) Regulation and legislation	0.052	0.027	0.028	0.038	0.057	0.033	0.028
5) Knowledge exchange	0.046	0.018	0.020	0.019	0.029	0.029	0.017
6) Design trends	0.207	0.265	0.279	0.264	0.229	0.232	0.249
7) Environment and sustainability	0.083	0.106	0.070	0.113	0.143	0.077	0.083

APPENDIX D: Normalized matrices of innovation factors

	Consultant (Normalized)						
	Lack of financial resources	Unsupportive organizational culture	Temporary nature of projects	Unavailability of materials	Lack of experienced and qualified	Lack of clear benefits	Time constraint
1) Lack of financial resources	0.415	0.418	0.302	0.257	0.469	0.372	0.416
2) Unsupportive organizational culture	0.138	0.139	0.189	0.200	0.117	0.159	0.166
3) Temporary nature of projects	0.052	0.028	0.038	0.057	0.033	0.027	0.028
4) Unavailability of materials	0.046	0.020	0.019	0.029	0.029	0.018	0.017
5) Lack of experienced and qualified staff	0.207	0.279	0.264	0.229	0.234	0.265	0.249
6) Lack of clear benefits	0.059	0.046	0.075	0.086	0.039	0.053	0.042
7) Time constraint	0.083	0.070	0.113	0.143	0.078	0.106	0.083

APPENDIX D: Normalized matrices of innovation factors

	Consultant (Normalized)					
	Capital	Investment in R&D	Internal knowledge management	External knowledge management	Consultancy	Innovation team
1) Capital	0.437	0.333	0.378	0.427	0.479	0.427
2) Investment in R&D	0.049	0.037	0.027	0.017	0.034	0.028
3) Internal knowledge management	0.062	0.074	0.054	0.043	0.048	0.047
4) External knowledge management	0.087	0.111	0.108	0.085	0.080	0.071
5) Consultancy	0.219	0.259	0.270	0.256	0.239	0.284
6) Innovation team	0.146	0.185	0.162	0.171	0.120	0.142

	Consultant (Normalized)					
	Effective Cooperation	Early Contractor Involvement	Leadership	Commitment	Reward schemes	Training Policy
1) Effective Cooperation	0.142	0.185	0.146	0.120	0.162	0.169
2) Early Contractor Involvement	0.028	0.037	0.049	0.034	0.027	0.028
3) Leadership	0.427	0.333	0.437	0.479	0.378	0.423
4) Commitment	0.284	0.259	0.219	0.239	0.270	0.254
5) Reward schemes	0.047	0.074	0.062	0.048	0.054	0.042
6) Training Policy	0.071	0.111	0.087	0.080	0.108	0.085

APPENDIX D: Normalized matrices of innovation factors

	Consultant (Normalized)			
	Short project duration	Increased productivity	Improved technical and managerial	Enhanced design trends
1) Shorter project duration	0.050	0.070	0.033	0.025
2) Increased productivity	0.450	0.630	0.691	0.525
3) Improved technical and managerial capability	0.350	0.210	0.230	0.375
4) Enhanced design trends	0.150	0.090	0.046	0.075

	Project management (Normalized)					
	Cost saving	Time saving	Quality improvement	Technology improvement	Construction safety	Market improvement
1) Cost saving	0.239	0.219	0.284	0.259	0.254	0.270
2) Time saving	0.479	0.437	0.427	0.333	0.423	0.378
3) Quality improvement	0.120	0.146	0.142	0.185	0.169	0.162
4) Technology improvement	0.034	0.049	0.028	0.037	0.028	0.027
5) Construction safety improvement	0.080	0.087	0.071	0.111	0.085	0.108
6) Market improvement	0.048	0.062	0.047	0.074	0.042	0.054

APPENDIX D: Normalized matrices of innovation factors

	Project management (Normalized)						
	Client requirement	Competition level	Project performance level	Regulation and legislation	Knowledge exchange	Design trends	Environment and sustainability
1) Client requirement	0.415	0.416	0.450	0.372	0.302	0.418	0.257
2) Competition level	0.083	0.083	0.075	0.106	0.113	0.070	0.143
3) Project performance improvement	0.207	0.249	0.225	0.265	0.264	0.279	0.229
4) Regulation and legislation	0.059	0.042	0.045	0.053	0.075	0.046	0.086
5) Knowledge exchange	0.052	0.028	0.064	0.027	0.038	0.028	0.057
6) Design trends	0.138	0.166	0.113	0.159	0.189	0.139	0.200
7) Environment and sustainability	0.046	0.017	0.028	0.018	0.019	0.020	0.029

	Project management (Normalized)					
	Capital	Investment in R&D	Internal knowledge management	External knowledge management	Consultancy	Innovation team
1) Capital	0.437	0.427	0.423	0.378	0.333	0.479
2) Investment in R&D	0.146	0.142	0.169	0.162	0.185	0.120
3) Internal knowledge management	0.087	0.071	0.085	0.108	0.111	0.080
4) External knowledge management	0.062	0.047	0.042	0.054	0.074	0.048
5) Consultancy	0.049	0.028	0.028	0.027	0.037	0.034
6) Innovation team	0.219	0.284	0.254	0.270	0.259	0.239

APPENDIX D: Normalized matrices of innovation factors

	Project management (Normalized)					
	Effective Cooperation	Early Contractor Involvement	Leadership	Commitment	Reward schemes	Training Policy
1) Effective Cooperation	0.142	0.185	0.146	0.120	0.162	0.169
2) Early Contractor Involvement	0.028	0.037	0.049	0.034	0.027	0.028
3) Leadership	0.427	0.333	0.437	0.479	0.378	0.423
4) Commitment	0.284	0.259	0.219	0.239	0.270	0.254
5) Reward schemes	0.047	0.074	0.062	0.048	0.054	0.042
6) Training Policy	0.071	0.111	0.087	0.080	0.108	0.085

APPENDIX D: Normalized matrices of innovation factors

	Project management (Normalized)									
	Modern methods of construction	Project management tools	Strategic partnering	Supply chain partnership	Energy efficiency/ sustainability	Building information modeling (BIM)	Advanced materials	Lean construction	Automation	Marketing
1) Modern methods of construction	0.341	0.304	0.269	0.198	0.217	0.389	0.345	0.241	0.414	0.182
2) Project management tools	0.068	0.061	0.090	0.110	0.109	0.043	0.043	0.103	0.052	0.109
3) Strategic partnering	0.057	0.030	0.045	0.088	0.081	0.032	0.029	0.069	0.041	0.091
4) Supply chain partnership	0.038	0.012	0.011	0.022	0.014	0.019	0.014	0.011	0.026	0.036
5) Energy efficiency/ sustainability	0.043	0.015	0.015	0.044	0.027	0.022	0.017	0.017	0.030	0.055
6) Building information modeling (BIM)	0.114	0.182	0.180	0.154	0.163	0.130	0.173	0.172	0.104	0.145
7) Advanced materials	0.085	0.122	0.135	0.132	0.136	0.065	0.086	0.138	0.069	0.127
8) Lean construction	0.049	0.020	0.022	0.066	0.054	0.026	0.022	0.034	0.035	0.073
9) Automation	0.171	0.243	0.224	0.176	0.190	0.259	0.259	0.206	0.207	0.164
10) Marketing	0.034	0.010	0.009	0.011	0.009	0.016	0.012	0.009	0.023	0.018

APPENDIX D: Normalized matrices of innovation factors

Project management (Normalized)				
	Short project duration	Increased productivity	Improved technical and managerial	Enhanced design trends
1) Shorter project duration	0.223	0.210	0.350	0.265
2) Increased productivity	0.670	0.630	0.450	0.618
3) Improved technical and managerial capability	0.032	0.070	0.050	0.029
4) Enhanced design trends	0.074	0.090	0.150	0.088

Owner (Normalized)						
	Cost saving	Time saving	Quality improvement	Technology improvement	Construction safety	Market improvement
1) Cost saving	0.239	0.219	0.284	0.270	0.254	0.259
2) Time saving	0.479	0.437	0.427	0.378	0.423	0.333
3) Quality improvement	0.120	0.146	0.142	0.162	0.169	0.185
4) Technology improvement	0.048	0.062	0.047	0.054	0.042	0.074
5) Construction safety improvement	0.080	0.087	0.071	0.108	0.085	0.111
6) Market improvement	0.034	0.049	0.028	0.027	0.028	0.037

APPENDIX D: Normalized matrices of innovation factors

	Owner (Normalized)						
	Client requirement	Competition level	Project performance level	Regulation and legislation	Knowledge exchange	Design trends	Environment and sustainability
1) Client requirement	0.415	0.372	0.465	0.302	0.257	0.418	0.416
2) Competition level	0.059	0.053	0.046	0.075	0.086	0.046	0.042
3) Project performance improvement	0.207	0.265	0.232	0.264	0.229	0.279	0.249
4) Regulation and legislation	0.052	0.027	0.033	0.038	0.057	0.028	0.028
5) Knowledge exchange	0.052	0.027	0.033	0.038	0.057	0.028	0.028
6) Design trends	0.138	0.159	0.116	0.189	0.200	0.139	0.166
7) Environment and sustainability	0.083	0.106	0.077	0.113	0.143	0.070	0.083

	Owner (Normalized)					
	Capital	Investment in R&D	Internal knowledge management	External knowledge management	Consultancy	Innovation team
1) Capital	0.437	0.427	0.378	0.423	0.333	0.479
2) Investment in R&D	0.146	0.142	0.162	0.169	0.185	0.120
3) Internal knowledge management	0.062	0.047	0.054	0.042	0.074	0.048
4) External knowledge management	0.087	0.071	0.108	0.085	0.111	0.080
5) Consultancy	0.049	0.028	0.027	0.028	0.037	0.034
6) Innovation team	0.219	0.284	0.270	0.254	0.259	0.239

APPENDIX D: Normalized matrices of innovation factors

	Owner (Normalized)						
	Lack of financial resources	Unsupportive organizational culture	Temporary nature of projects	Unavailability of materials	Lack of experienced and qualified	Lack of clear benefits	Time constraint
1) Lack of financial resources	0.415	0.418	0.257	0.302	0.465	0.372	0.416
2) Unsupportive organizational culture	0.138	0.139	0.200	0.189	0.116	0.159	0.166
3) Temporary nature of projects	0.046	0.020	0.029	0.019	0.029	0.018	0.017
4) Unavailability of materials	0.052	0.028	0.057	0.038	0.033	0.027	0.028
5) Lack of experienced and qualified staff	0.207	0.279	0.229	0.264	0.232	0.265	0.249
6) Lack of clear benefits	0.059	0.046	0.086	0.075	0.046	0.053	0.042
7) Time constraint	0.083	0.070	0.143	0.113	0.077	0.106	0.083

APPENDIX D: Normalized matrices of innovation factors

	Owner (Normalized)									
	Modern methods of construction	Project management tools	Strategic partnering	Supply chain partnership	Energy efficiency/ sustainability	Building information modeling (BIM)	Advanced materials	Lean construction	Automation	Marketing
1) Modern methods of construction	0.341	0.414	0.304	0.217	0.198	0.345	0.389	0.182	0.269	0.241
2) Project management tools	0.171	0.207	0.243	0.190	0.176	0.259	0.259	0.164	0.224	0.206
3) Strategic partnering	0.068	0.052	0.061	0.109	0.110	0.043	0.043	0.109	0.090	0.103
4) Supply chain partnership	0.043	0.030	0.015	0.027	0.044	0.017	0.022	0.055	0.015	0.017
5) Energy efficiency/ sustainability	0.038	0.026	0.012	0.014	0.022	0.014	0.019	0.036	0.011	0.011
6) Building information modeling (BIM)	0.085	0.069	0.122	0.136	0.132	0.086	0.065	0.127	0.135	0.138
7) Advanced materials	0.114	0.104	0.182	0.163	0.154	0.173	0.130	0.145	0.180	0.172
8) Lean construction	0.034	0.023	0.010	0.009	0.011	0.012	0.016	0.018	0.009	0.009
9) Automation	0.057	0.041	0.030	0.081	0.088	0.029	0.032	0.091	0.045	0.069
10) Marketing	0.049	0.035	0.020	0.054	0.066	0.022	0.026	0.073	0.022	0.034

APPENDIX D: Normalized matrices of innovation factors

	Owner (Normalized)			
	Short project duration	Increased productivity	Improved technical and managerial	Enhanced design trends
1) Shorter project duration	0.630	0.670	0.450	0.618
2) Increased productivity	0.210	0.223	0.350	0.265
3) Improved technical and managerial capability	0.070	0.032	0.050	0.029
4) Enhanced design trends	0.090	0.074	0.150	0.088

	Supplier (Normalized)					
	Cost saving	Time saving	Quality improvement	Technology improvement	Construction safety	Market improvement
1) Cost saving	0.085	0.087	0.080	0.108	0.071	0.111
2) Time saving	0.423	0.437	0.479	0.378	0.427	0.333
3) Quality improvement	0.254	0.219	0.239	0.270	0.284	0.259
4) Technology improvement	0.042	0.062	0.048	0.054	0.047	0.074
5) Construction safety improvement	0.169	0.146	0.120	0.162	0.142	0.185
6) Market improvement	0.028	0.049	0.034	0.027	0.028	0.037

APPENDIX D: Normalized matrices of innovation factors

	Supplier (Normalized)						
	Client requirement	Competition level	Project performance level	Regulation and legislation	Knowledge exchange	Design trends	Environment and sustainability
1) Client requirement	0.415	0.372	0.418	0.257	0.302	0.465	0.416
2) Competition level	0.059	0.053	0.046	0.086	0.075	0.046	0.042
3) Project performance improvement	0.138	0.159	0.139	0.200	0.189	0.116	0.166
4) Regulation and legislation	0.046	0.018	0.020	0.029	0.019	0.029	0.017
5) Knowledge exchange	0.052	0.027	0.028	0.057	0.038	0.033	0.028
6) Design trends	0.207	0.265	0.279	0.229	0.264	0.232	0.249
7) Environment and sustainability	0.083	0.106	0.070	0.143	0.113	0.077	0.083

	Supplier (Normalized)					
	Capital	Investment in R&D	Internal knowledge management	External knowledge management	Consultancy	Innovation team
1) Capital	0.239	0.284	0.270	0.254	0.259	0.219
2) Investment in R&D	0.120	0.142	0.162	0.169	0.185	0.146
3) Internal knowledge management	0.048	0.047	0.054	0.042	0.074	0.062
4) External knowledge management	0.080	0.071	0.108	0.085	0.111	0.087
5) Consultancy	0.034	0.028	0.027	0.028	0.037	0.049
6) Innovation team	0.479	0.427	0.378	0.423	0.333	0.437

APPENDIX D: Normalized matrices of innovation factors

	Supplier (Normalized)						
	Lack of financial resources	Unsupportive organizational culture	Temporary nature of projects	Unavailability of materials	Lack of experienced and qualified	Lack of clear benefits	Time constraint
1) Lack of financial resources	0.415	0.465	0.372	0.302	0.416	0.257	0.418
2) Unsupportive organizational culture	0.207	0.232	0.265	0.264	0.249	0.229	0.279
3) Temporary nature of projects	0.059	0.046	0.053	0.075	0.042	0.086	0.046
4) Unavailability of materials	0.052	0.033	0.027	0.038	0.028	0.057	0.028
5) Lack of experienced and qualified staff	0.083	0.077	0.106	0.113	0.083	0.143	0.070
6) Lack of clear benefits	0.046	0.029	0.018	0.019	0.017	0.029	0.020
7) Time constraint	0.138	0.116	0.159	0.189	0.166	0.200	0.139

	Supplier (Normalized)					
	Effective Cooperation	Early Contractor Involvement	Leadership	Commitment	Reward schemes	Training Policy
1) Effective Cooperation	0.142	0.185	0.146	0.169	0.162	0.120
2) Early Contractor Involvement	0.028	0.037	0.049	0.028	0.027	0.034
3) Leadership	0.427	0.333	0.437	0.423	0.378	0.479
4) Commitment	0.071	0.111	0.087	0.085	0.108	0.080
5) Reward schemes	0.047	0.074	0.062	0.042	0.054	0.048
6) Training Policy	0.284	0.259	0.219	0.254	0.270	0.239

APPENDIX D: Normalized matrices of innovation factors

	Supplier (Normalized)									
	Modern methods of construction	Project management tools	Strategic partnering	Supply chain partnership	Energy efficiency/ sustainability	Building information modeling (BIM)	Advanced materials	Lean construction	Automation	Marketing
1) Modern methods of construction	0.341	0.182	0.241	0.269	0.304	0.389	0.414	0.198	0.345	0.217
2) Project management tools	0.034	0.018	0.009	0.009	0.010	0.016	0.023	0.011	0.012	0.009
3) Strategic partnering	0.049	0.073	0.034	0.022	0.020	0.026	0.035	0.066	0.022	0.054
4) Supply chain partnership	0.057	0.091	0.069	0.045	0.030	0.032	0.041	0.088	0.029	0.081
5) Energy efficiency/ sustainability	0.068	0.109	0.103	0.090	0.061	0.043	0.052	0.110	0.043	0.109
6) Building information modeling (BIM)	0.114	0.145	0.172	0.180	0.182	0.130	0.104	0.154	0.173	0.163
7) Advanced materials	0.171	0.164	0.206	0.224	0.243	0.259	0.207	0.176	0.259	0.190
8) Lean construction	0.038	0.036	0.011	0.011	0.012	0.019	0.026	0.022	0.014	0.014
9) Automation	0.085	0.127	0.138	0.135	0.122	0.065	0.069	0.132	0.086	0.136
10) Marketing	0.043	0.055	0.017	0.015	0.015	0.022	0.030	0.044	0.017	0.027

APPENDIX D: Normalized matrices of innovation factors

	Supplier (Normalized)			
	Short project duration	Increased productivity	Improved technical and managerial	Enhanced design trends
1) Shorter project duration	0.223	0.210	0.265	0.350
2) Increased productivity	0.670	0.630	0.618	0.450
3) Improved technical and managerial capability	0.074	0.090	0.088	0.150
4) Enhanced design trends	0.032	0.070	0.029	0.050

APPENDIX E: Average and Overall ranking for innovation factors

Consultant (w=50.25%)	
	Average
1) Cost saving	0.26
2) Time saving	0.424
3) Quality improvement	0.144
4) Technology improvement	0.033
5) Construction safety improvement	0.085
6) Market improvement	0.054
	Average
1) Client requirement	0.38
2) Competition level	0.06
3) Project performance improvement	0.154
4) Regulation and legislation	0.039
5) Knowledge exchange	0.025
6) Design trends	0.246
7) Environment and sustainability	0.097
	Average
1) Lack of financial resources	0.38
2) Unsupportive organizational culture	0.158
3) Temporary nature of projects	0.037
4) Unavailability of materials	0.022

5) Lack of experienced and qualified staff		0.243
6) Lack of clear benefits		0.061
7) Time constraint		0.096
	Average	
1) Capital		0.414
2) Investment in R&D		0.032
3) Internal knowledge management		0.055
4) External knowledge management		0.091
5) Consultancy		0.255
6) Innovation team		0.154
	Average	
1) Effective Cooperation		0.154
2) Early Contractor Involvement		0.034
3) Leadership		0.413
4) Commitment		0.254
5) Reward schemes		0.055
6) Training Policy		0.090
	Average	
1) Modern methods of construction		0.152
2) Project management tools		0.210
3) Strategic partnering		0.109
4) Supply chain partnership		0.015
5) Energy efficiency/ sustainability		0.079
6) Building information modeling (BIM)		0.290
7) Advanced materials		0.056
8) Lean construction		0.020

9) Automation		0.040
10) Marketing		0.028
	Average	
1) Shorter project duration		0.044
2) Increased productivity		0.574
3) Improved technical and managerial capability		0.291
4) Enhanced design trends		0.090

APPENDIX E: Average and Overall ranking for innovation factors

Project management (w=26.02)	
	Average
1) Cost saving	0.231
2) Time saving	0.45
3) Quality improvement	0.143
4) Technology improvement	0.032
5) Construction safety improvement	0.088
6) Market improvement	0.053
	Average
1) Client requirement	0.376
2) Competition level	0.096
3) Project performance improvement	0.246
4) Regulation and legislation	0.058
5) Knowledge exchange	0.042
6) Design trends	0.158
7) Environment and sustainability	0.025
	Average
1) Lack of financial resources	0.389
2) Unsupportive organizational culture	0.146
3) Temporary nature of projects	0.038
4) Unavailability of materials	0.025

5) Lack of experienced and qualified staff		0.25
6) Lack of clear benefits		0.057
7) Time constraint		0.094
	Average	
1) Capital		0.423
2) Investment in R&D		0.154
3) Internal knowledge management		0.090
4) External knowledge management		0.055
5) Consultancy		0.034
6) Innovation team		0.254
	Average	
1) Effective Cooperation		0.157
2) Early Contractor Involvement		0.038
3) Leadership		0.453
4) Commitment		0.214
5) Reward schemes		0.058
6) Training Policy		0.080
	Average	
1) Modern methods of construction		0.290
2) Project management tools		0.079
3) Strategic partnering		0.056
4) Supply chain partnership		0.020
5) Energy efficiency/ sustainability		0.028
6) Building information modeling (BIM)		0.152
7) Advanced materials		0.109
8) Lean construction		0.040

9) Automation		0.210
10) Marketing		0.015
	Average	
1) Shorter project duration		0.262
2) Increased productivity		0.592
3) Improved technical and managerial capability		0.045
4) Enhanced design trends		0.101

APPENDIX E: Average and Overall ranking for innovation factors

Owner (w=13.44%)	
	Average
1) Cost saving	0.234
2) Time saving	0.444
3) Quality improvement	0.145
4) Technology improvement	0.056
5) Construction safety improvement	0.089
6) Market improvement	0.033
	Average
1) Client requirement	0.366
2) Competition level	0.061
3) Project performance improvement	0.252
4) Regulation and legislation	0.04
5) Knowledge exchange	0.03
6) Design trends	0.156
7) Environment and sustainability	0.095
	Average
1) Lack of financial resources	0.378
2) Unsupportive organizational culture	0.158
3) Temporary nature of projects	0.025

4) Unavailability of materials		0.037
5) Lack of experienced and qualified staff		0.247
6) Lack of clear benefits		0.058
7) Time constraint		0.096
	Average	
1) Capital		0.413
2) Investment in R&D		0.154
3) Internal knowledge management		0.055
4) External knowledge management		0.090
5) Consultancy		0.034
6) Innovation team		0.254
	Average	
1) Effective Cooperation		0.254
2) Early Contractor Involvement		0.055
3) Leadership		0.413
4) Commitment		0.090
5) Reward schemes		0.034
6) Training Policy		0.154
	Average	
1) Modern methods of construction		0.288
2) Project management tools		0.210
3) Strategic partnering		0.079
4) Supply chain partnership		0.028
5) Energy efficiency/ sustainability		0.020
6) Building information modeling (BIM)		0.101
7) Advanced materials		0.152

8) Lean construction		0.025
9) Automation		0.056
10) Marketing		0.040
	Average	
1) Shorter project duration		0.592
2) Increased productivity		0.262
3) Improved technical and managerial capability		0.045
4) Enhanced design trends		0.101

APPENDIX E: Average and Overall ranking for innovation factors

Supplier (w=3.48%)	
	Average
1) Cost saving	0.084
2) Time saving	0.459
3) Quality improvement	0.229
4) Technology improvement	0.053
5) Construction safety improvement	0.142
6) Market improvement	0.033
	Average
1) Client requirement	0.378
2) Competition level	0.058
3) Project performance improvement	0.158
4) Regulation and legislation	0.025
5) Knowledge exchange	0.037
6) Design trends	0.247
7) Environment and sustainability	0.096

	Average
1) Lack of financial resources	0.37
2) Unsupportive organizational culture	0.242
3) Temporary nature of projects	0.06
4) Unavailability of materials	0.037
5) Lack of experienced and qualified staff	0.1
6) Lack of clear benefits	0.025
7) Time constraint	0.165
	Average
1) Capital	0.254
2) Investment in R&D	0.154
3) Internal knowledge management	0.055
4) External knowledge management	0.090
5) Consultancy	0.034
6) Innovation team	0.413
	Average
1) Effective Cooperation	0.154
2) Early Contractor Involvement	0.034
3) Leadership	0.413
4) Commitment	0.090
5) Reward schemes	0.055
6) Training Policy	0.254

	Average
1) Modern methods of construction	0.290
2) Project management tools	0.015
3) Strategic partnering	0.040
4) Supply chain partnership	0.056
5) Energy efficiency/ sustainability	0.079
6) Building information modeling (BIM)	0.152
7) Advanced materials	0.210
8) Lean construction	0.020
9) Automation	0.109
10) Marketing	0.028
	Average
1) Shorter project duration	0.262
2) Increased productivity	0.592
3) Improved technical and managerial capability	0.101
4) Enhanced design trends	0.045