Critical Success Factors for Implementing Off-Site Modular Construction projects in UAE: A Fuzzy DEMATEL Approach

عوامل النجاح الحاسمة لتنفيذ مشاريع الإنشاءات الجاهزة و المعيارية بدولة الإمارات العربية المتحدة

by

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ABSTRACT

Offsite Modular Construction, have started gaining popularity in the middle east in the last few years as it is seen to improve quality, reduce construction time and reduce safety related accidents.

This research studied and found the influence and relationship between different critical success factors related to the implementation of offsite construction. the research first identified Critical Success Factors (CSFs) from literature review, then grouping the factors into Principal Success Factors (PSFs) using the affinity diagram method through consulting offsite modular construction experts. A survey found the ranking of the critical success factor and the DEMATEL (Decision Making Trial and Evaluation Laboratory), which is Multi-Criteria Decision Making (MCDM) method, was used with fuzzy set theory methods for finding the causes, effects and influences between the different PSFs to assist executives in taking strategic high level decisions. Fuzzy-DEMATEL was also used for finding the causes, effects and influences between the CSFs which would help project managers and professionals in taking project level decision.

After analyzing the data to find the causes, effects and relationships between the different factors, the results of the study found that 5 PSFs and 15 CSFs were causes while 2 PSFs and 10 CSFs were effects. This approach can be considered for future and more extensive research on this subject.

ملخص البحث

بدأت مشاريع الإنشاءات الجاهزة و المعيارية تتكسب شعبية في الشرق الأوسط في الاعاوم الماضية لأنها ترفع من الجودة و تقلل من وقت التنفيذ و ايضا تقلل من الحوادث المتعلقة بالسلامة.

درس هذا البحث التأثير والعلاقة بين العوامل المختلفة المتعلقة بتنفيذ المشاريع المعيارية من خلال تحديد عوامل النجاح الحاسمة (CSFs) من مراجعة الأدبيات ، ثم تجميع العوامل في عوامل النجاح الرئيسية (PSFs)باستخدام (Affinity Diagram) من خلال استشارة خبراء بالبناء المعياري، ، ثم تم استخدام DEMATEL لايجاد التأثير و العلاقة بين عوامل النجاح الرئيسية (PSF) لمساعدة الادارة التنفيذية لاخذ القرارات الاستراتيجية. كما تم استخدام DEMATEL لايجاد التأثير و العلاقة بين عوامل النجاح الحاسمة (CSF) لمساعدة المشاريع والمهنيين لاخذ القرارات على مستوى المشاريع.

نتائج البحث اظهرت ان خمسة (5) من عوامل النجاح الرئيسية (PSF) و خمسة عشر (15) من عوامل النجاح الحاسمة (CSF) هي من فئة الاسباب و ان اثنان (2) من عوامل النجاح الرئيسية (PSF) و عشرة (10) من عوامل النجاح الحاسمة (CSF) هي من فئة التأثير . يمكن النظر في هذا النهج للبحث المستقبلي والأكثر شمولاً حول هذا الموضوع.

ACKNOWLEDGEMENTS

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LIST OF DEFINITIONS AND ABBREVIATIONS

AHP:	Analytic Hierarchy Process
BIM:	Building Information Modeling
BUiD:	British University in Dubai
CSF:	Critical Success Factor
DEMATEL:	Decision Making Trial and Evaluation Laboratory
GCC:	Gulf Cooperation Council
IBS:	Industrialized Building Systems
LEED:	Leadership in Energy and Environmental Design
MCDM:	Multi-Criteria Decision Making
MEP:	Mechanical, Electrical & Plumbing
MiC:	Modular Integrated Construction
OMC:	Offsite Modular Construction
PMI:	Project Management Institute
PSF:	Principal Success Factor
TFN:	Triangular Fuzzy Number
UAE:	United Arab Emirates

LIST OF CSFS

CSF1	Good Communication and Collaboration between all stakeholders
CSF2	Fabricator Experience in Modules
CSF3	Robust drawing specifications and early design freeze
CSF4	Early Advice from Experts and Professionals
CSF5	Effective Use of IT Resources (e.g. BIM)
CSF6	Experience and Knowledge of Key players
CSF7	Precise project planning and control
CSF8	Standardization for mass production
CSF9	On-site and Off-site Coordination
CSF10	Supply Chain Coordination and Control
CSF11	Alignment of Modules and Project Requirements
CSF12	Manpower and Technicians' Experience
CSF13	Continuous Improvement
CSF14	Early Economic Analysis & Scope Definition
CSF15	Suitable Procurement and Contracting Strategies
CSF16	Availability of Local transportation infrastructure
CSF17	Availability of Key members at the earliest stages
CSF18	Effective coordination and management of stakeholders
CSF19	Early Involvement of Suppliers and Fabricators
CSF20	Appreciation of the Impact of Early Decisions
CSF21	Supply Chain Risk Management
CSF22	Availability of Skilled Technicians and supervisors
CSF23	Consideration of Module Limitations
CSF24	Early completion and cost savings recognition
CSF25	Top Management Support and Involvement in Decision Making

LIST OF PSFS

PSF1	Project Coordination & Quality Management
PSF2	Human Resources Management
PSF3	Design & Specification Control & Management
PSF4	Procurement Control
PSF5	Early Commitment & Engagement
PSF6	Schedule Planning & Stakeholder Management
PSF7	Cost Control & Management

CHAPTER I: INTRODUCTION

1.1 Research Background

With the rising number in every country's population and with the higher technological advancements in the past few decades, the demand for new construction has been increasing significantly every year. While the construction industry has been booming, researchers have noted that the construction industry has not been keeping up with the rapid advancement in technologies that have been happening, unlike other industries like manufacturing (Ginigaddara et al, 2021).

In the past few years, the middle east construction industry has grown exponentially in preparation for the 2020 Dubai Expo, 2022 World Cup in Qatar, etc and to cover the huge increase in population over the past few decades. During this time the middle east has seen the construction of thousands of new buildings, which have created a great opportunity for governments, investors, designers, and contractors. With these huge investments by different parties, there is a need for ensuring the best quality with the least costs, most investors and builders wanted to build as fast and efficiently as possible.

During this time the governments have also enforced new regulations for green buildings and different green building rating systems were introduced, while some authorities have made them mandatory for all new projects, e.g. the Abu Dhabi government and the Estidama rating systems, some authorities didn't mandate it but have encouraged the application of international green building certifications like the LEED (Leadership in Energy and Environmental Design) rating system.

While these rating systems are targeting many different aspects of the construction of buildings, like the use of energy and water-efficient appliances, materials, and the overall

improvement of indoor air quality, it is worth noting that waste reduction is one of the corner stones of these rating systems.

The competition between different companies, government regulations, and overall environmental requirements have led people to look for innovative ideas like the utilization of Building Information Modeling (BIM) and Off-Site Modular Construction. “The concept of offsite construction is not new – it dates back to the 1800s. Although appeared with different names” (Goulding et al, 2014). While some companies have started implementing these methods it is by far still not the first choice for all.

Building Information Modelling (BIM) is one of the newest developments and trends that were created in recent years. “Building information modelling, or BIM, involves [the] development and use of computer-generated models to manage and integrate the essential building design with project data in different phases of a building’s life cycle” (Chiu et al, 2020).

Offsite Modular construction, is a manufacturing process in which various construction works or parts of it would be done at a specialist facility and not in situ at the construction sites. The most significant advantages of off-site building over traditional methods are time and cost savings, as well as the ability to improve quality and sustainable environmental issues in addition to it helping in the reduction of Health and Safety risks as most of the construction would be done in a controlled environment (Xu et al, 2020). According to Ginigaddara et al (2022), one of the main causes of failure in the traditional construction industry is the extensive dependence on human skills, and this is one of the main causes of the rise of offsite construction. while

Multiple Studies have discussed the benefits of offsite construction, while the theoretical benefits discussed in these studies seem very lucrative, it is worth noting that offsite construction methods are still not as popular as traditional in situ construction methods.

While studying the benefits is great, research is also required for finding the problems and difficulties associated with offsite construction. Several studies were done to find the critical success factors for certain types of offsite construction projects in other countries, but few studies and research were found on the critical success factors for the implementation of offsite construction in the Middle East, GCC or the United Arab Emirates and thus this study focuses on and aims to identify and find the effects and relationship between the critical success factors of Off-Site Modular Construction in Construction Projects in the United Arab Emirates from the perspective of UAE offsite construction industry experts.

1.2 Problem Statement

Due to the extreme competition and the limited opportunities in the construction industry, seeking innovation is not only beneficial it is also mandatory to some extent. This extreme competition between construction contractors has forced contractors to think outside the box and think of different methods and ways for reducing their costs and thus bidding at lower rates. The rise of green building construction concepts/ ideas and new government regulations have reduced material waste a priority which has also helped in pushing for the off-site construction methodologies.

Offsite Modular Construction (OMC) is not by any chance mandated by the authorities and there are many different approaches that can be taken instead of and/ or in addition to the implementation of OMC. OMC has gained more popularity recently and has been implemented a lot recently as many professionals have praised the benefits and opportunities (like time and

financial savings from manpower and waste reduction) that can be gained, it should be noted here that with these benefits and opportunities come risks and difficulties, like bigger upfront costs and the requirements of a more skilled work-force at the design and implementation levels. It is important that one can weigh the opportunities and risks and identify the different variables and their effects on the overall success and/ or failure of implementing OMC. The dissertation aims to research, study and find the critical success factors for the implementation of OMC using the scientific methods

1.3 Research Aims and Objectives

Offsite Modular Construction (OMC) has gained popularity recently in the United Arab Emirates and it was noticed that a few companies have started partially implementing different OMC techniques in new projects. Unfortunately, due to the limited scientific research done on the critical success factors of offsite modular construction in the United Arab Emirates, it seems like companies rely on personal experiences, word of mouth, and trial and error rather than relying on scientific research and data analysis.

The main objective of this dissertation is to identify the critical success factors for implementing OMC in the United Arab Emirates, which shall be done by finding different factors and variables and their effects on the successful implementation of OMC. After finding the factors and by using mainly a multi-criteria decision-making data analysis technique called DEMATEL for weighing up and finding the significance and relations between the causes and effects, this would help in finding the most critical success factors. By doing so this paper aims to help professionals and managers in making a scientifically informed decision for a complex problem.

1.4 Dissertation Structure

This dissertation contains five main sections, a reference section, and some additional information and data in the appendices. The **Introduction** section contains a brief introduction to the dissertation in addition to the aims and objectives. The **Literature Review** section contains a detailed discussion of literature that was researched in the preparation of this research dissertation. The **Research Methodology section** includes a detailed discussion of the statistical methods that were followed in this dissertation in addition to a detailed discussion of the data collected. The **Data Analysis and Findings** section discusses in detail the analysis done for the data gathered and the findings from the analysis and The **Conclusion** section as the name suggests concludes and discusses the findings of the dissertation. The **References** section contains the references and sources cited in this dissertation, and finally, the **Appendices** section contains extra material that was not fully detailed in this dissertation.

CHAPTER II: LITERATURE REVIEW

2.1 Terminologies and Definitions

2.1.1 Prefabrication, Offsite and Modular Construction

Prefabrication construction, also known as prefab, industrialized construction and/or offsite construction, the term modular construction is also used sometimes along with or in lieu of offsite construction, as the majority of offsite construction and prefabrication requires splitting the project activities into smaller parts or modules. While prefabrication can be called by different names, these terms are usually used interchangeably to describe when construction-related activities are done in a controlled industrialized environment whether it is done in a factory or in a specified area in a construction site rather than performing the construction activities in situ on the actual site. Prefabrication expedites building delivery especially for construction in remote locations and for mass construction. The use of prefabrication in full building construction or system assembly has been implemented way before the 1700s but has evolved significantly over the centuries that followed especially by learning from the industrial manufacturing techniques from the likes of Ford. The advancement in manufacturing methods and overall technologies have helped in the overall improvement in quality and reduction in costs for prefabrication construction (Smith, 2010; Knaak et al, 2011; El Abidi et al, 2019; Wuni et al, 2020; Ginigaddara et al, 2022). The Most commonly defined benefits and advantages of Offsite Construction are increased productivity, reduction in the overall project duration, improved quality control, the reduction in manpower requirements, the environmental benefits caused by waste reduction and overall savings in costs even though offsite construction projects would usually have higher upfront costs. (Goulding and Rahimian, 2019).

Knaak et al (2011) have explained that the use of Prefabricated systems in construction involves precise pre-planning for the components and/ or modules to increase quality and efficiency, to do so companies need to be very cautious and follow the highest standards to reduce the overall costs. It is worth noting here that these days the technologies available and the previous experiences in prefabrication are available, accessible and can be used to implement prefabrication or offsite construction efficiently. The use of prefabrication and/ or modular construction is not new as there are examples that can be found from a few centuries ago, but recently with the help of newer technologies companies are now able to create more complex modules offsite.

The term offsite refers to the fact that usually this method involves carrying out the works in a different location and the term modular refers to the fact that this technique involves the splitting of components into modules for fabrication offsite prior to delivering and installation at the actual site. The terms prefabrication, offsite construction, and modular construction are used interchangeably in the UAE construction industry most of the times. It is worth noting here that offsite construction is a general term and it can refer to many different methods and aspects in construction projects, some companies implement the use of precast concrete panels, prefabricated Façade Panels or Offsite modular MEP installations to name a few.

While Offsite construction is not a very new method as there are some researchers who have traced back some prefabricated buildings and elements to as far as the eleventh century as found by the Roman and Greek settlements in the Mediterranean areas (El-Abidi et al, 2019), it has gained popularity recently with the advancement in technologies and systems, sophisticated software Building Information Modeling software like Autodesk Revit have made it easier to implement precise factory manufacturing techniques for construction activities.

Gbadamosi (2018) has concluded that the offsite construction can benefit from the use of BIM for efficiently selecting material, minimizing waste and expediting project execution. El-Abidi et al (2019) have studied and concluded that the use of prefabricated/ offsite construction methods can be very rewarding especially for developing countries who are suffering from shortage of housing and would benefit from the speed that the implementation of prefabrication can offer.

Figures 1 and 2 below show Crystal Palace which was built for the London Great Exhibition in 1851 within 8 months via the use of prefabricated modules and connections in a factory and assembly at site. This was a very innovative building at that time, especially since most buildings then were made of stone and a building of such size and structure would have taken several years to complete, the designer for the Crystal palace relied on making typical modules and parts to be fabricated in a factory, these modules would then be transported to site and erected by unskilled workers. Of course all the modules, panels were designed in a way to be coordinated and sized with all other systems like the drainage, natural ventilation and day light in mind (Knaak, 2011). This great achievement was done prior to the availability of computers and/ or any modeling software.

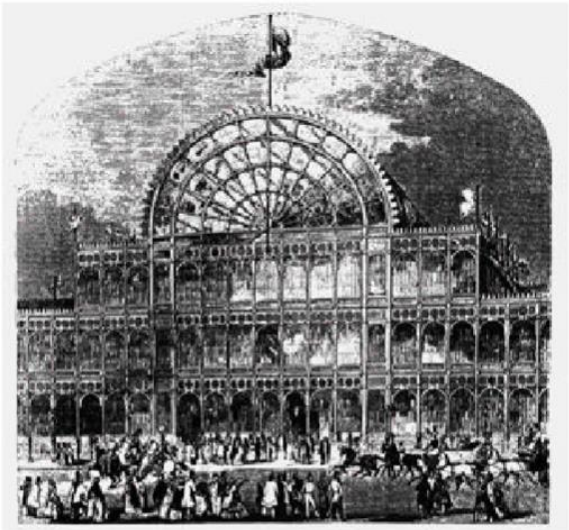


Figure 1 - Crystal Palace (London 1851)

designed for the London Great Exhibition. "All modules, components and connections were manufactured in the factory" (Knaak, 2011)

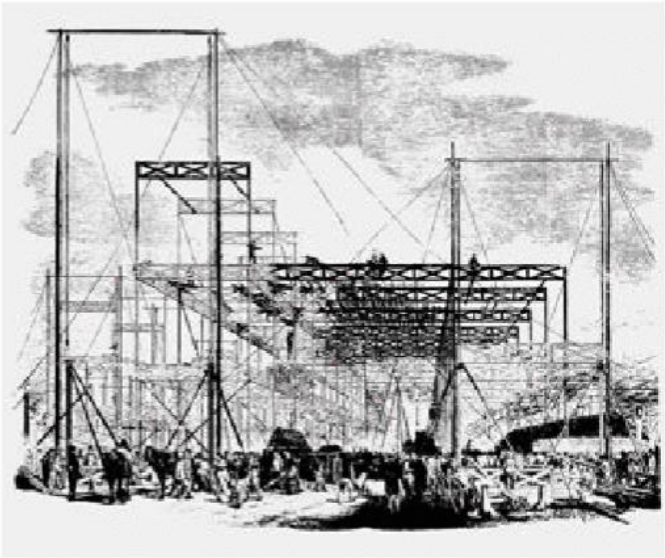


Figure 2 - Crystal Palace Modules
"all components down to the window mullions and sashes were engineered to integrate natural ventilation, lighting and drainage. (Knaak, 2011)

2.1.2 Building Information Modeling

Building Information Modeling (BIM) is one of the newer technologies that have gained great popularity in the past 2 decades. As the name suggests Building Information Modeling is process in which all elements related to a construction project are modeled virtually by computer software, to visualize and simulate the different systems in a building. BIM has been a driving force in the advancements in the AEC (Architecture, Engineering & Construction) and Facility Management fields, as the information can be accessed and viewed on the 3d model and changes can be easily modeled on BIM prior to the construction execution at site (Epstein, 2012). BIM can be used to precisely model different building elements separately and in coordination with the other systems and elements, and BIM is very often used for the clash detection capabilities to detect and rectify clashes prior to execution. Figure 3 Below shows renders from BIM and matching photos for the final installation, the renders and photos are taken from the new Jotun MEIA Headquarter in Dubai Science Park, Dubai, United Arab Emirates.

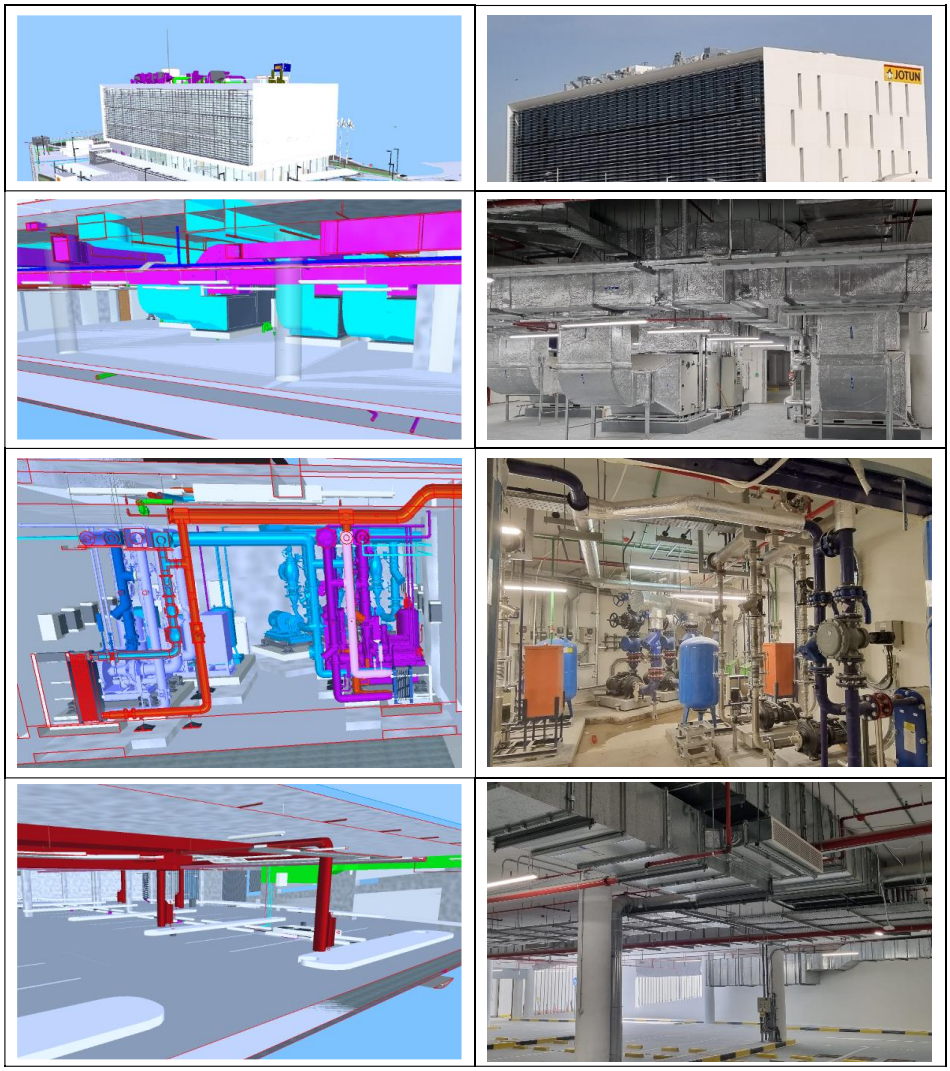


Figure 3 - Autodesk Navisworks Renders on the Left and Actual Installation Photos on the right from the new Jotun MEIA HQ

2.1.3 Critical Success Factors

Many define that a project can be called successful if the project is completed within the specified time, budget, and technical requirements and/or specifications (Camilleri, 2016). After defining what is considered successful, the next task will be to find what leads to the success of a project, which is a really difficult task since projects are different in scope and requirements, additionally there is some subjectivity and different people will have different opinions on how to quantitively measure the success of a project and what are the factors that will lead to a better success (Abraham, 2003).

Leidecker and Bruno (1984) have defined Critical Success Factors as the "few key areas where 'things must go right' for the business to flourish. If the results in these areas are not adequate, the organization's efforts for the period will be less than defined". The Critical Success Factors method has been there for a few decades there are a few mentions of it from the 1960s and 1970s, but it started gaining popularity in the 1980s especially after Rockart examined and worked on the strategies and methodologies for the MIS industry in Particular (Abraham, 2003). Several studies have grouped critical success factors and have called them Principal Success Factors (PSFs) as it helps in the study and the presentation of results, different techniques for grouping can be used based on the data available and aims of the studies.

2.1.4 Affinity Diagram

Affinity Diagrams, also known as the KJ Method, is an effective method for grouping or clustering different factors or ideas based on common topics and relationships. The final product of this method, which is a simple diagram, is the result of brainstorming sessions of a small team that preferably has co-workers who have some experience working together previously (Han and Deng, 2018; Awasthi and Chauhan, 2013; Ryan, 2011). Even though it was first developed and used in the field of quality management, it has gained popularity as it is an effective decision making and idea generating technique which usually involves verbal discussions with some note taking and recording.

2.1.5 Fuzzy Set Theory

One of the biggest problems faced once collecting data from experts and professionals is that their judgements and opinions are very subjective, once rating an item they will usually use a scale from 1 – 5, 1 – 10 or by using subjective words like "Strongly Agree", "Agree", "Disagree" or "Strongly Disagree", the problem is that to each person these ratings might mean something different and this would usually cause some sort of vagueness which hinders the

analysis process. Fuzzy Set Theory solves these problems by assigning multiple values of partial truths to each rating in order to find a quantifiable objective "crisp values" to overcome the vagueness and imprecision of judgements, and fuzzy numbers can be used in conjunction with other statistical methods to reduce the biases of the participants. (Lin, 2013; Islam et al, 2019; Wuni et al, 2020a, Wuni and Chen, 2022).

2.1.6 DEMATEL

The **DE**cision **MA**king **T**rial and **E**valuation **L**aboratory (DEMATEL) is a powerful tool for multi-criteria decision making which makes it easier to find the causes and effects which will be a great addition after finding the weighting and rank of the potential critical and principal success factor. Du and Zhou (2019) have summarized that DEMATEL "is aimed at describing the basic concept of contextual relations and identifying cause–effect chain components/factors for a complex decision problem".

Wu (2012) has summarized that DEMATEL is a technique in which different causes and effects are represented in a visual directed graphs which is easier to read than directionless graphs. Wu (2012) also explained that fuzzy set theory is powerful tool for representing data mathematically by numbers, "each number between 0 and 1 indicates a partial truth, whereas crisp sets correspond to binary logic: 0 or 1. Hence, fuzzy set theory can express and handle vague or imprecise judgments mathematically."

The use of Fuzzy DEMATEL is going to be used to check the relation among the different Critical/ Principal Success Factors identified. Making an informed decision would require weighing up the relationships between the factors based on their qualitative factors, and thus using fuzzy set theory and DEMATEL will help in expediting reaching a more realistic decision-making process.

As discussed previously, the end result of DEMATEL will be a visual diagram that would show the criticality of each factor and its influence on another. A more detailed description of DEMATEL will be further discussed in subsequent sections of this report. Figure 4 below shows a sample taken from a paper by Wu (2012)

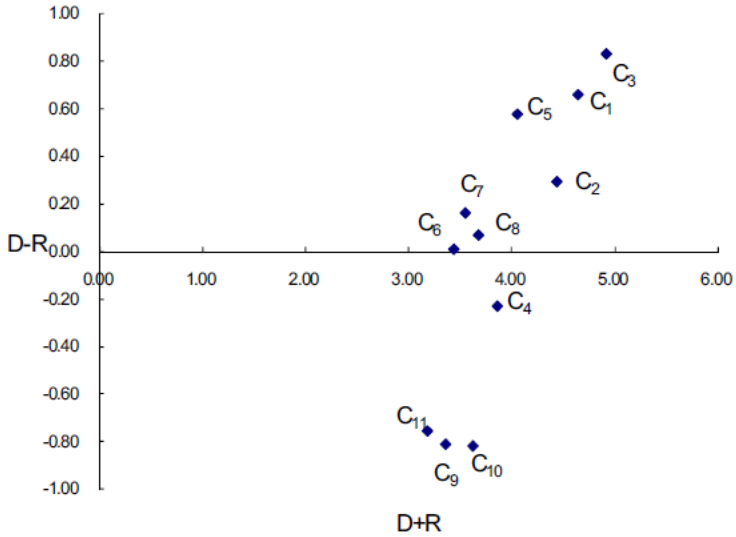


Figure 4 - Causal Diagram Sample (Wu, 2012)

2.2 Critical Success Factors of Modular Construction in other countries

The definition of success is different from one person to the other, however the common definition of success for a project mean meeting or exceeding the planned objectives and unique expectations, like the timeline, budget, quality, etc.., of the major stakeholders, not all offsite modular construction projects succeed in meeting these expectations and objectives due to several factors (Wuni et al, 2020). Of course not all factors are weighted equally, some factors are more critical than others, the Critical Success Factors (CSFs) are the most important areas that might make or break a project, this would allow professionals to make informed decisions by providing enough focus and resources are for these CSFs, to increase the chances for actual success in projects' delivery.

Making informed decisions based on finding the critical success factors by using the scientific and statistical methods is a better approach than taking decisions based on personal preferences and ideas. Different researchers and professionals have studied the critical success factors for prefabrication and/ or modular construction in other countries, but although these results are extensive and detailed, it is wrong to assume that such research can be applicable to every country or region, because different regions might have different critical factors that might not be as critical in other regions.

Due to the limited number of published and peer reviewed research done on this dissertation topic, it is really hard to find the actual CSFs required for offsite modular construction in the United Arab Emirates from literature review only. However, a few research papers were done on similar topics like quantitively evaluating critical success factors for modular integrated construction projects (Wuni et al, 2020a), reviewing critical success factors for modular integrated construction projects (Wuni and Shen, 2020b), studying the integrating circular economy with modular construction (Wuni and Shen, 2022), studying CSFs for industrialized building systems (El-Abidi et al, 2018), research for finding the critical factors for implementing just in time concept in modular integrated construction (Hussein and Zayed, 2020) and research done to find the critical success factors for Building Information Modeling (Antwi-Afari et al, 2018). The critical success factors from the previous mentioned papers were found using different techniques and since they were done in different circumstances and different places they can't be used and implemented directly into this dissertation but the critical success factors found were taken into consideration, however the criticality and rank for these factors will not be taken into consideration in this research, and instead the factors gathered were used as a base for the potential CSFs that will be discussed in detail with subject matter experts.

Hussein and Zayed (2020) studied another topic and took another approach in their research, their main concern/ idea was studying the impact of improving the modular construction by targeting a specific problem which they felt was a major barrier in Modular Construction projects which is the supply chain/ logistics. In their research they synthetically analyzed previous studies and researches and performed a meta analysis on the critical factors they found.

Wuni and Shen (2020b) found 35 Critical Success Factors for the implementation of Modular Construction by researching 55 different previous researches and papers for projects implemented in Europe, North America, Asia and Australia between 1993 – 2019. Table 1 summarizes their findings.

Table 1- CSFs for MiC implementation (Wuni and Shen, 2020b)

Sr	CSFs	Total Ref.	Rank
1	Good working collaboration, effective communication, and information sharing among MiC project participants	17	1
2	Improved supply chain coordination and management	14	2
3	Accurate design, early design freeze and timely owner's approval	11	3
4	Fully-integrated approach and involvement of key participants throughout the project	11	3
5	Suitable procurement strategy and contracting	11	3
6	Standardization, optimization, and benchmarking of best practices	11	3
7	Extensive MiC project planning, scheduling and control	10	7
8	Early and effective use of information and communication technology	9	8
9	Effective stakeholder MiC management starting with clearly defined goals and priorities of all involved stakeholders	9	8
10	Effective management of stakeholder, supply chain and project execution risks	9	8
11	Adequate relevant experience and knowledge of contractor, designed and manufacturer of MiC projects	9	8
12	Adequate resources of owner, planning, team support and decision support systems	7	12
13	Top management support and early involvement of in the MiC supply chain	7	12
14	Early and precise definition of MiC project engineering scope, planning and budget	6	14
15	Fabricator infrastructure, experience, and capabilities in modules design and production	6	14

Sr	CSFs	Total Ref.	Rank
16	Availability of local transport infrastructure, equipment, heavy lift and site transport capabilities	6	14
17	Alignment of modules architecture and long-term collaboration among fabricators, suppliers, designers, subcontractors and contractors	6	14
18	Early advice and modularization consideration from MiC design professionals and experts	5	18
19	Alignment on MiC project drivers	5	18
20	Owner-furnished long-lead equipment specification	4	20
21	Module envelope limitations	4	20
22	Early completion and cost savings recognition	4	20
23	Well-informed contractor leadership	4	20
24	Owner delay avoidance	4	20
25	Lead time and space hedging and transport delay avoidance	4	20
26	Realistic systematic economic analysis and early decisions	4	20
27	Design robustness, flexibility and system integration	4	20
28	Continuous improvement and learning	4	20
29	Availability of experienced work force and supervising team with technical capabilities	4	20
30	Key decisions should be understood and made as early as possible between all parties involved	3	30
31	Intensive early research on modularization and commitment from owners	3	30
32	Reasonable lead time to allow for pre-site prototyping and trial assembly or stacking of modules in the factory	2	32
33	Effective coordination of off-site and on-site construction activities	2	32
34	Systematic performance measuring and re-use of experiences	2	32
35	Adequate modular design code, specification, regulations, and performance management systems	2	32

El-Abidi et al (2018) researched CSFs of Industrialized Building system (IBS) in Malaysia, IBS is a term that is used in Malaysia to refer to using offsite manufactured standardized prefabricated construction related components. In their study they found 15 CSFs by identifying potential factors from literature review and then confirming them through multiple rounds of survey questionnaires that were answered by 3 different groups. Table 2 summarizes their findings.

Table 2 - CSFs for IBS in Malaysia (El-Abidi et al, 2018)

Critical Success Factors	Rank According to Government Participants	Rank According to Academic Participants	Rank According to Contractors & Manufacturers
Government leadership	1	1	8
National policy	2	4	1
Corporate leadership	4	7	4
Business strategy	6	8	4
Government incentives	3	2	2
Private investment	5	2	7
Design management and integration	11	6	6
Project management	11	10	6
Supply chain management and logistics	11	10	6
Skills	7	5	11
Training and education	8	12	9
Corporate human resources management	9	11	10
Easy access guarantee	10	9	3
Technology enhancement	10	9	3
Research and development	10	3	5

Wuni et al (2022) found 23 CSFs and 3 Principal Success Factors for managing and implementing Hong Kong based Circular Modular Construction, that was done through the implementation of fuzzy synthetic evaluation of a survey that was answered by 117 different individuals with varying experiences working in different roles and companies. Table 3 summarizes their findings.

Table 3 - PSFs & CSFs for circular modular construction projects in Hong Kong (Wuni and Shen, 2022)

ID	Critical success factors/Principal success factors
PSF1	***Effective supply chain management***
CSF22	Use of hedging strategies and transport delay avoidance
CSF10	Integrating circular economy principles into the supply chain of modular construction projects
CSF8	Extensive upfront planning for circular modular construction projects
CSF17	Effective management of critical tolerances between interfaces
CSF7	Design for manufacture, assembly, and circular economy
CSF23	Adequate lead time for the bespoke processes of circular modular construction projects

ID	Critical success factors/Principal success factors
CSF14	Effective coordination of onsite and offsite work packages
CSF20	Use of just-in-time delivery arrangement
PSF2	***Competence and early commitment***
CSF18	Early engagement of certification body for factory inspection
CSF3	Effective leadership and support of a specialist contractor
CSF1	Adequate knowledge and experience of the project team
CSF6	Suitable site characteristics and layout
CSF2	Early understanding and commitment of the client
CSF11	Early and active involvement of critical project stakeholders
CSF15	Using suitable structural system and construction material
CSF5	Early design completion and freezing
PSF3	***Collaboration and information management***
CSF4	Collaborative working and information sharing among project teams
CSF13	Leveraging information from demolition and design lifecycle stages
CSF16	Effective use of building information modeling
CSF12	Effective coordination and integration of stakeholders
CSF9	Use of collaborative procurement system and contracting

Wuni et al (2020a) focused on researching the critical success factors for the implementation and success of Modular Integrated Construction (MiC) in projects, for their study they identified 25 potential CSFs from researching different articles, research and journals, after they shortlist these 25 potential CSFs they were able to get to identify and evaluate these CSFs through approaching Subject Matter Experts from different countries and then confirming/ gathering further data through questionnaires. The data gathered was statistically analyzed and then evaluated through the use of fuzzy synthetic methods to identify that the 4 Principal Success Factors (PSFs) found were all critical for the success of Modular Construction projects. Table 4 and Figure 5 provide a summary of the findings of Wuni et al's (2020a) research.

Table 4 - CSF and PSF Summary (Wuni et al, 2020)

S.N.	CSF and PSF
PSF1	***Adequate technical capability and infrastructure***
CSF1	Fabricator experience and capabilities in modules design and production
CSF8	Experienced workforce and technical capability
CSF12	Availability of sound local transport infrastructure and site equipment capabilities
CSF10	Availability of skilled workforce, management and supervising team

S.N.	CSF and PSF
CSF16	Adequate experience and knowledge of key players
PSF2	***Effective stakeholder and supply chain management***
CSF19	Suitable procurement strategy and contracting
CSF7	Extensive project planning, scheduling and control
CSF5	Effective coordination of the supply chain segments
CSF15	Effective coordination of on-site and off-site trades
CSF3	Good working collaboration, effective communication and information sharing among project participants
CSF25	Effective use of information and communication technology (e.g. BIM)
CSF14	Effective coordination and management of stakeholders
CSF6	Availability and active involvement of key project participants at the earliest stages of the project
CSF22	Effective supply chain and execution risk management
PSF3	***Early commitment***
CSF21	Appreciation of key early decisions and their implication between all parties involved
CSF9	Early involvement of modules suppliers and fabricators
CSF11	Early advice and consideration from MiC design experts and professionals
CSF2	Robust drawing specification and early design freeze
CSF24	Module envelope limitations
CSF23	Early completion and cost savings recognition
CSF13	Realistic economic analysis, early decision and definition of project scope
CSF20	Support and early involvement of top management in supply chain decision making
PSF4	***Standardization and benchmarking***
CSF18	Continuous improvement
CSF17	Alignment on MiC project drivers and modules architecture
CSF4	Standardization and mass production

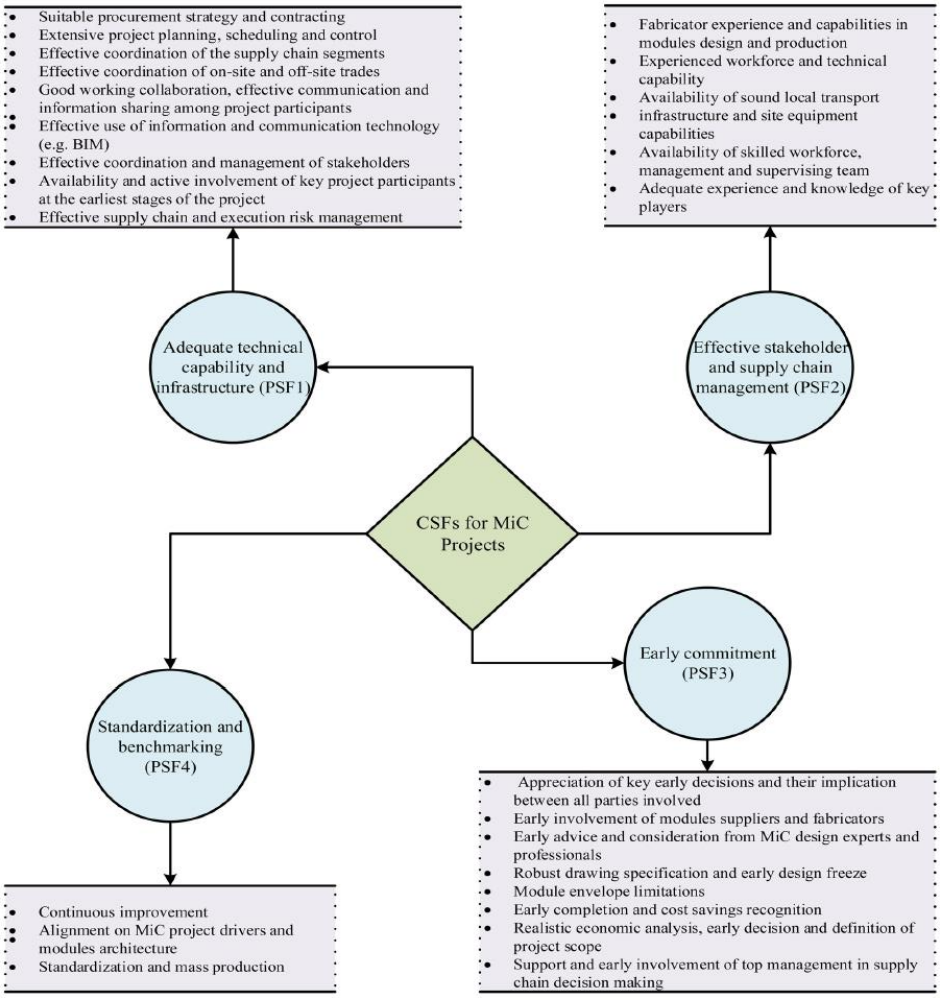


Figure 5 - "Conceptual Framework of the CSFs for MiC Projects" (Wuni et al, 2020)

2.3 Literature Summary and Potential Factors

To find a consolidated list of potential success factors, the research discussed in section 2.2 were taken into consideration. After compiling and comparing these lists together, it was noticed that there are a lot of items that are very similar and there are items that are not applicable to this dissertation as the previous surveys were targeting different problems.

All these potential factors were discussed with a team of 5 experienced experts from the GCC region to filter the irrelevant and duplicated items and compile a single list. After careful consideration and several rounds of discussions it was decided to go with the 25 potential success factors listed in table 5 as they were found to be very suitable. It shall be noted that any grouping and all ratings and rankings of similar factors found by the different papers

were disregarded as their studies were not done for UAE and/ or GCC projects, and instead it was decided that a survey questionnaire targeting professionals from the local industry only was held to find the criticality and importance of these potential factors.

Table 5 - Potential Success Factors

Sr.	Potential Critical Factors
F1	Fabricator Experience in Modules
F2	Robust drawing specifications and early design freeze
F3	Good Communication and Collaboration between all stakeholders
F4	Standardization for mass production
F5	Supply Chain Coordination and Control
F6	Availability of Key members at the earliest stages
F7	Precise project planning and control
F8	Manpower and Technicians' Experience
F9	Early Involvement of Suppliers and Fabricators
F10	Availability of Skilled Technicians and supervisors
F11	Early Advice from Experts and Professionals
F12	Availability of Local transportation infrastructure
F13	Early Economic Analysis & Scope Definition
F14	Effective coordination and management of stakeholders
F15	On-site and Off-site Coordination
F16	Experience and Knowledge of Key players
F17	Alignment of Modules and Project Requirements
F18	Continuous Improvement
F19	Suitable Procurement and Contracting Strategies
F20	Top Management Support and Involvement in Decision Making
F21	Appreciation of the Impact of Early Decisions
F22	Effective Use of IT Resources (e.g. BIM)
F23	Supply Chain Risk Management
F24	Early completion and cost savings recognition
F25	Consideration of Module Limitations

Due to the difficulties in finding enough professional participants the survey data was not enough for use as a base for decision making, and while several methods were considered for this dissertation, it was decided to go for the DEMATEL approach, which is suitable for analyzing the valuable input from a limited number of experts from the UAE construction industry. DEMATEL doesn’t only rank the factors based on their criticality, it also defines factors as causes and effects, and most importantly it finds the relationships between the

different factors and presents it in an easy-to-follow graphical visualization which would be helpful for project managers and executives in decision making for implementing offsite and modular construction methodologies in future projects (Li, 2013). Additionally, Fuzzy Set Theory was paired and used in this research, which is a technique preferred by several researchers to remove the "fuzziness" caused by using generic terms like Not critical, critical, very critical, etc… by using weights and functions to ease the subjectivity in experts' judgments and opinions. (Wuni et al, 2020a).

CHAPTER III: RESEARCH METHODOLOGY

3.1 Introduction

Data analysis couldn't be completed without collecting data first through expert interviews and questionnaire surveys. Surveys have become fundamental for collecting data on any given matter. Scholars, professionals and organizations use this technique as an indispensable instrument to know the behavior of their interest groups and make decisions about them.

It needs to be pointed out that the data collected alone is not enough for taking informed decisions, the data needs to be processed and analyzed. For this dissertation research subject matter experts' opinions and surveys have been taken into consideration to develop the critical risk factors for the implementation of Offsite modular construction in the UAE region.

The research process will include 3 major activities, listed below and summarized in figure 6:

1. Researching through a very detailed literature review and consulting Subject Matter Experts
2. Data Collection through surveys, workshop meetings and then further detailed discussions with the subject matter experts.
3. Statistical Data Analysis, representation, and discussion.

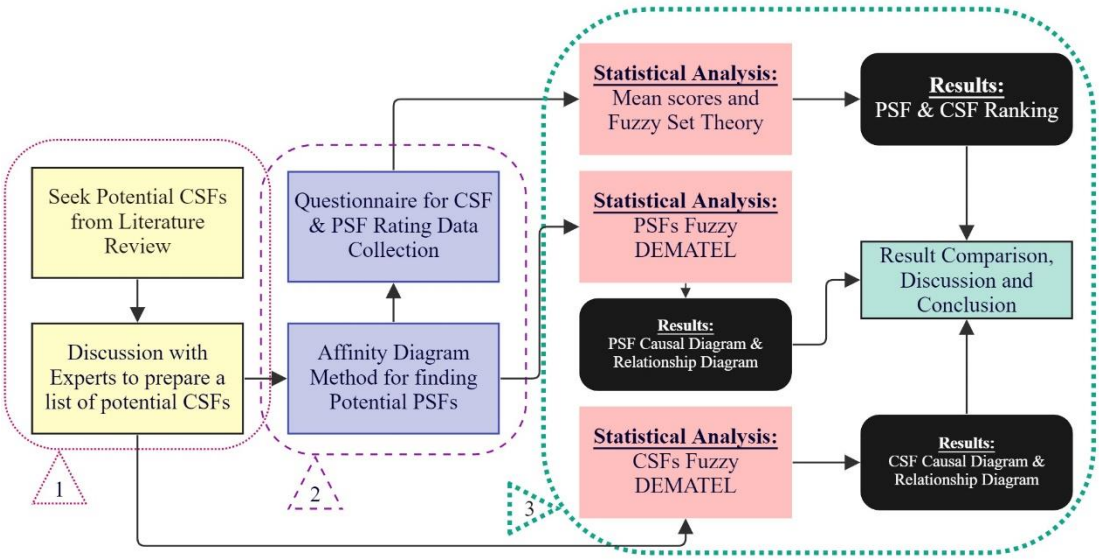


Figure 6 - Methodology Flowchart

3.2 Finding Potential CSFs by Literature Review and Expert Interviews

The first step for the research study is finding potential factors, which is a comprehensive literature review of multiple published studies on similar topics and then compiling a list of potential success factors. Since there is no research done on the same topic for this dissertation, the collected data from the literature review needs to be discussed in detail with UAE-based modular construction experts to refine and define a list of potential factors that apply to the UAE construction industry. Multiple rounds of discussion with different experts are required to ensure that the list is comprehensive and not biased towards a single expert's opinions.

3.3 Affinity Diagram Methodology

Affinity Diagrams proposed for grouping the factors are commonly used in research as Han and Deng (2018) and Awasthi and Chauhan (2013) have used this method with other multicriteria decision making techniques like DEMATEL and AHP, and they have summarized the steps as described in Figure 7.

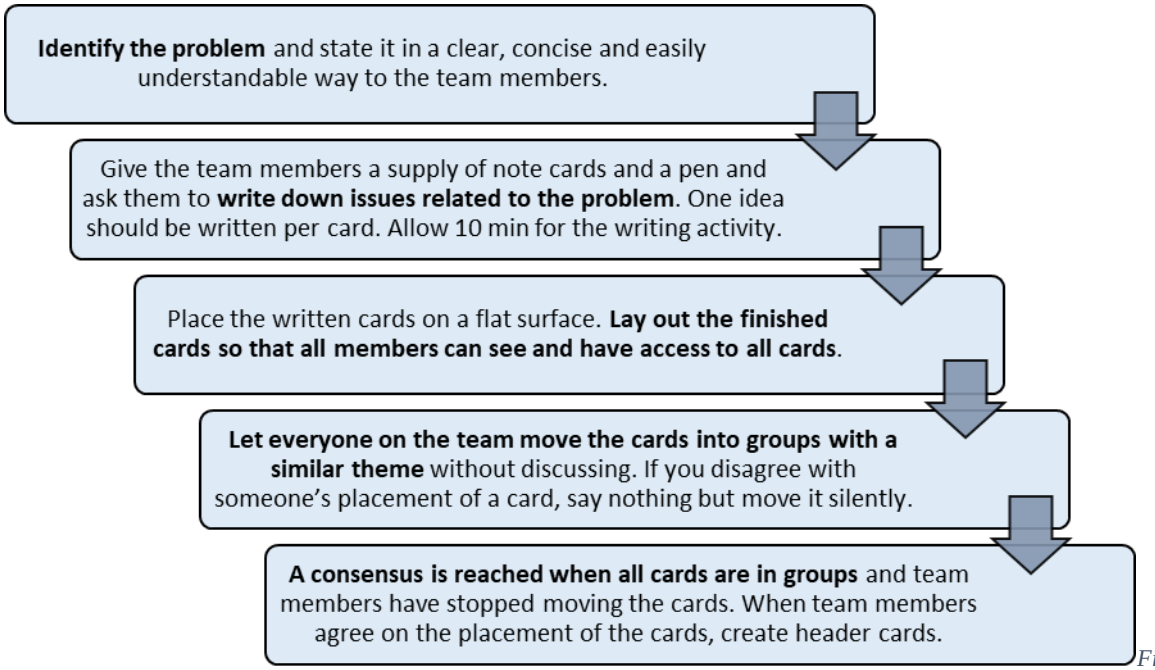


Figure 7 - Affinity Diagram Steps

3.4 Survey Questionnaire

For this part, a survey is to be floated to professionals with different backgrounds and experiences asking them to rate each of the potential factors on a scale of 1 to 5. The data is compiled, and the factors are ranked based on their mean scores. Fuzzy set theory shall be used to remove the biases and vagueness in the participant's answers.

3.5 Triangular Fuzzy Set Numbers

There are different types of fuzzy numbers, Triangular Fuzzy Numbers (TFN) are widely used for DEMATEL research like the studies done by Islam et al (2019), Du and Zhou (2019), Kiani Mavi and Standing (2018) and Lin (2013) to name a few. The basic idea of TFN is to represent and assign 3 different numbers to each rating value, for example, a rating of 1 on a scale of 1 – 5 which represents "No Influence at all" corresponds to TFN matrix of (0, 0.1, 0.3) and a rating of 2 on a scale of 1 – 5 which represents "Low Influence" corresponds to TFN matrix of (0.1, 0.3, 0.5). this means that since different people have different judgements a rating of 1 for a person might overlap with a rating of 2 for another, figure 12 shows a graphical

representation of 2 different TFNs intersecting. A summary of the proposed TFN numbers used for this dissertation can be found in table 6 which is based on the findings of Lin (2013).

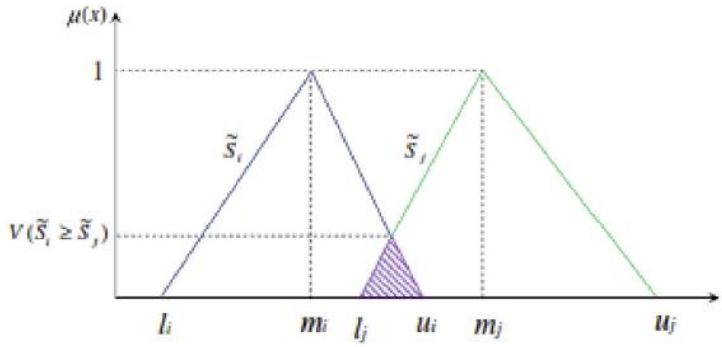


Figure 8 - Triangular Fuzzy Number Representation (Kiani Mavi and Standing, 2018)

Table 6 - Fuzzy Linguistic Scale (Lin, 2013)

Rating	Linguistic Term	TFN
1	No Influence	(0 , 0.1 , 0.3)
2	Very Low Influence	(0.1 , 0.3 , 0.5)
3	Moderate Influence	(0.3 , 0.5 , 0.7)
4	High Influence	(0.5 , 0.7 , 0.9)
5	Very High Influence	(0.7 , 0.9 , 1)

According to Lin (2013) and Wu (2012) the main objective of using a Fuzzy Set is to remove the vagueness of the linguistic variables and replace them with crisp score numbers that can be used in further analysis. The score can be found by following the following steps that were laid out by Lin (2013) and Wu (2012):

- <u>Definitions:</u>

z	Weighted average
(l,m,r)	Fuzzy number
i & j	Criterion i affects criterion j
k	Fuzzy questionnaire respondent number

- <u>Step 1:</u> Convert the linguistic variables or ratings into the TFNs from table 7.

  Sample TFN matrix for respondent 1 after (Step 1):

j / *i*	*1*	*2*	*...*	*j*

1	$(l_{11}^1, m_{11}^1, r_{11}^1)$	$(l_{12}^1, m_{12}^1, r_{12}^1)$	...	$(l_{1j}^1, m_{1j}^1, r_{1j}^1)$
2	$(l_{21}^1, m_{21}^1, r_{21}^1)$	$(l_{22}^1, m_{22}^1, r_{22}^1)$	...	$(l_{2j}^1, m_{2j}^1, r_{2j}^1)$
⋮	...	...	...	...
i	$(l_{i1}^1, m_{i1}^1, r_{i1}^1)$	$(l_{i2}^1, m_{i2}^1, r_{i2}^1)$	...	$(l_{ij}^1, m_{ij}^1, r_{ij}^1)$

- <u>Step 2:</u> Normalize the TFNs with the following formulas

$$xl_{ij}^k = \left(l_{ij}^k - \min\left(l_{ij}^k\right)\right)/\Delta_{min}^{max}$$

$$xm_{ij}^k = \left(m_{ij}^k - \min\left(m_{2ij}^k\right)\right)/\Delta_{min}^{max}$$

$$xr_{ij}^k = \left(r_{ij}^k - \min\left(r_{ij}^k\right)\right)/\Delta_{min}^{max}$$

$$Where\ \Delta_{min}^{max} = max\left(r_{ij}^k\right) - \min(l_{ij}^k)$$

Sample normalized TFN matrix after for respondent 1 (after Step 2):

i \ ***j***	***1***	***2***	***...***	***j***
1	$(xl_{11}^1, xm_{11}^1, xr_{11}^1)$	$(xl_{12}^1, xm_{12}^1, xr_{12}^1)$	...	$(xl_{1j}^1, xm_{1j}^1, xr_{1j}^1)$
2	$(xl_{21}^1, xm_{21}^1, xr_{21}^1)$	$(xl_{22}^1, xm_{22}^1, xr_{22}^1)$	...	$(xl_{2j}^1, xm_{2j}^1, xr_{2j}^1)$
⋮	...	...	...	...
i	$(xl_{i1}^1, xm_{i1}^1, xr_{i1}^1)$	$(xl_{i2}^1, xm_{i2}^1, xr_{i2}^1)$	...	$(xl_{ij}^1, xm_{ij}^1, xr_{ij}^1)$

- <u>Step 3:</u> Find left and right normalized values (ls & rs)

$$xls_{ij}^k = xm_{ij}^k/(1 + xm_{ij}^k - xl_{ij}^k)$$

$$xrs_{ij}^k = xr_{ij}^k/(1 + xr_{ij}^k - xm_{ij}^k)$$

Sample left and right normalized TFN matrix after for respondent 1 (after Step 3):

i \ ***j***	***1***	***2***	***...***	***j***
1	(xls_{11}^1, xrs_{11}^1)	(xls_{12}^1, xrs_{12}^1)	...	(xls_{1j}^1, xrs_{1j}^1)
2	(xls_{21}^1, xrs_{21}^1)	(xls_{22}^1, xr_{22}^1)	...	(xls_{2j}^1, xrs_{2j}^1)
⋮	...	...	...	...
i	(xls_{i1}^1, xrs_{i1}^1)	(xls_{i2}^1, xrs_{i2}^1)	...	(xls_{ij}^1, xrs_{ij}^1)

- <u>Step 4:</u> Calculate the total normalized crisp value

$$x_{ij}^k = \frac{\left[xls_{ij}^k * \left(1 - xls_{ij}^k\right) + \left(xrs_{ij}^k * xrs_{ij}^k\right)\right]}{\left(1 - xls_{ij}^k + xrs_{ij}^k\right)}$$

Sample Total Normalized Crisp Value matrix after for respondent 1 (after Step 4):

i \ j	1	2	…	j
1	(x_{11}^1)	(x_{12}^1)	…	(x_{1j}^1)
2	(x_{21}^1)	(x_{22}^1)	…	$(x_{2j},)$
⋮	…	…	…	…
i	(x_{i1}^1)	(x_{i2}^1)	…	(x_{ij}^1)

- Step 5: Calculate the crisp value

$$z_{ij}^k = \min\left(a_{ij}^k\right) + (x_{ij}^k * \Delta_{min}^{max})$$

Sample Crisp Value matrix after for respondent 1 (after Step 4):

i \ j	1	2	…	j
1	(z_{11}^1)	(z_{12}^1)	…	(z_{1j}^1)
2	(z_{21}^1)	(z_{22}^1)	…	$(z_{2j},)$
⋮	…	…	…	…
i	(z_{i1}^1)	(z_{i2}^1)	…	(z_{ij}^1)

Many different software can be used for doing these calculations, but after thorough research and after breaking down the calculations step by step, it was decided that these calculations can be done by Microsoft Excel by using simple equations and formulas.

3.6 DEMATEL

The Traditional Decision Making Trial and Evaluation Laboratory (DEMATEL) is a powerful Multi-Criteria Decision Making technique that was developed in the 1970s, and it is a good option to be used as it relies on comparing the data gathered from a limited group of experts to build cause and effect relationship models/ visualization graphics and has been widely used by different researchers over the past few decades. (Lin, 2013; Islam et al, 2019; Kiani Mavi and Standing, 2018; Qi et al, 2020; Wu, 2012). For this dissertation Microsoft excel was used for doing the data analysis. Figure 8 provides a visual summary of the traditional DEMATEL methodology.

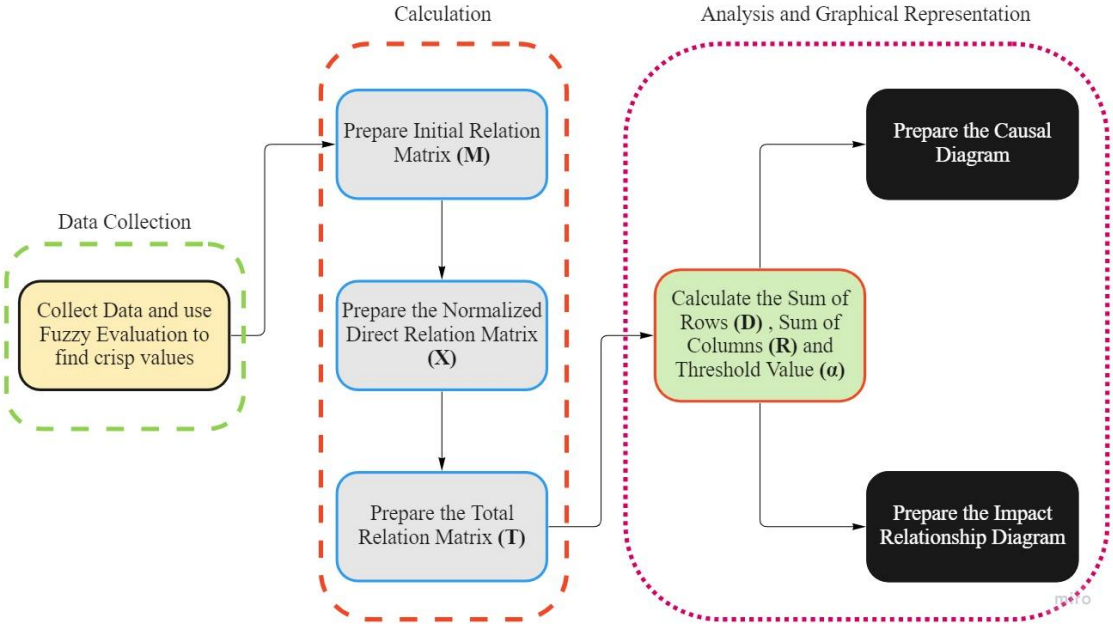


Figure 9 - DEMATEL Methodology Summary

The DEMATEL process consists of the following steps:

- <u>Step 1:</u>
    - A questionnaire for the relationship between the different factors needs to be filled out by multiple experts, since this questionnaire is not very typical a workshop meeting was held to thoroughly discuss and explain the questionnaire.
    - The Experts were asked to use a scale of 1 to 5 as shown in Table 7.
    - Sample Questionnaire:

	PSF1	**PSF2**	**PSF3**	**PSF4**	**PSF5**
PSF1					
PSF2					
PSF3					
PSF4					

PSF5					

- The cells that are highlighted in dark blue are not to be filled
- In the cells, the expert was asked to fill in the effect of the row item on the column

- After gathering the data from multiple experts, Fuzzy set theory is done to find the crisp values.

- <u>Step 2:</u>
  - The Initial Relation Matrix (M) is prepared, factors in this matrix are referred to as *"m_{ij}"* where:
    - m_{ij}: refers to the degree of effect of "i" on "j"
    - i: refers to row
    - j: refers to column
  - Sample M-Matrix:

j / i	**PSF1**	**PSF2**	**…**	**PSFj**
PSF1		m_{12}	...	m_{1j}
PSF2	m_{21}		...	m_{2j}
⋮	⋮	⋮		⋮
PSFi	m_{i1}	m_{i2}	...	

- <u>Step 3</u>:
  - The Normalized Direct Relation Matrix (X) is prepared, factors in this matrix are referred to as *"x_{ij}"* where:
    - $x_{ij} = s_{ij} * m_{ij}$
      - i: refers to row
      - j: refers to column

- $s_{ij} = \frac{1}{\max_{1 \le i \le n} \sum_{j=1}^{n} m_{ij}}, where\ i, j = 1,2, \dots, n$

- Sample X-Matrix:

i \ j	PSF1	PSF2	…	PSFj
PSF1		x_{12}	…	x_{1j}
PSF2	x_{21}		…	x_{2j}
⋮	⋮	⋮		⋮
PSFi	x_{i1}	x_{i2}	…	

- <u>Steps 4:</u>

  - The Total Relation Matrix (T) is prepared, factors in this matrix are referred to as "t_{ij}"
  - $T = X(I - X)^{-1}$
    - Where I is the identity matrix.
    - Calculating the T matrix required the use of 2 matrix formulas in Microsoft Excel which are:
      - MINVERSE: to find the inverse of a matrix.
      - MMULT: to multiply matrices.
  - After Finding T matrix, Calculating the Sum of Rows "D" and the sum of columns "R":
    - $D_i = \sum_{j=1,2,\dots n}^{n} t_{ij}$
    - $R_j = \sum_{i=1,2,\dots n}^{n} t_{ij}$
  - Sample T matrix with D and R:

i \ j	PSF1	PSF2	…	PSFj	D
PSF1		t_{12}	…	t_{1j}	D_1
PSF2	t_{21}		…	t_{2j}	D_2

⋮	⋮	⋮		⋮	
PSFi	t_{i1}	t_{i2}	...		D_i
R	R_1	R_2		R_j	

- <u>Step 5:</u>
  - Causal Diagram to be prepared by Calculating the following:
    - <u>D+R:</u>
      - Will be referred to as the influence (horizontal) axis
      - It will indicate the influence between different factors
    - <u>D-R:</u>
      - Will be referred to as the relationship (vertical) axis
      - It will indicate the relationship of different factors:
        - Positive Value means "Cause"
        - Negative Value means "Effect"
  - Sample Causal Diagram Table (Table 7) and Plot (Figure 10):

Table 7 - Sample DEMATEL Table

Factor	D	R	D+R	D-R	Remarks
PSF1	0.149	0.177	0.326	-0.027	**EFFECT**
PSF2	0.149	0.162	0.312	-0.013	**EFFECT**
PSF3	0.189	0.175	0.364	0.0144	**CAUSE**
PSF4	0.147	0.146	0.293	0.0019	**CAUSE**
PSF5	0.173	0.149	0.323	0.0247	**CAUSE**

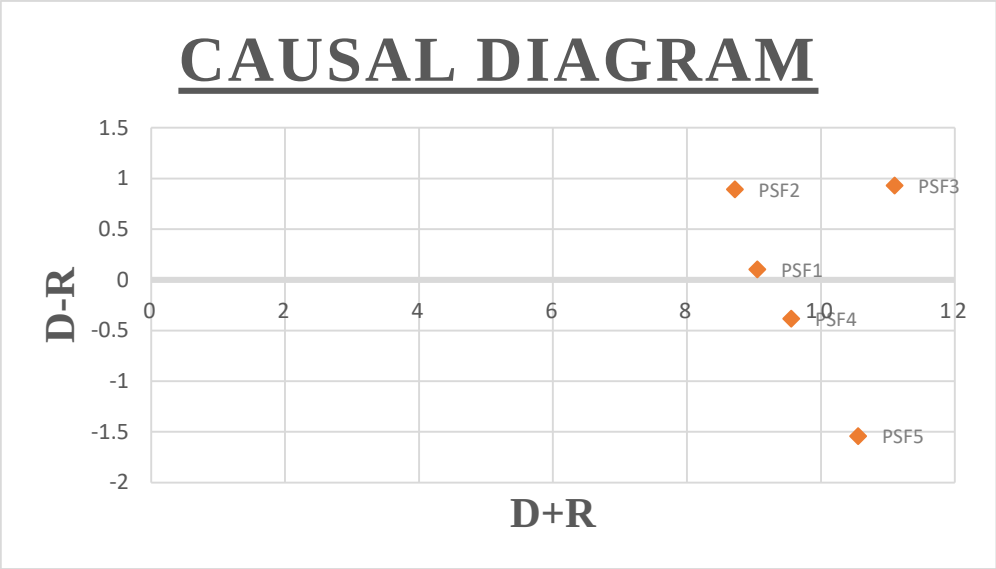


Figure 10 - Sample DEMATEL Causal Diagram

- <u>Step 6:</u>
  - Preparing the impact relationship diagram between the different factors, by calculating the following:
    - $Threshold\ Value\ (\alpha) = average\ (t_{ij})$
    - Any t value that is above the threshold value means that there is an impact of "i" on "j"
    - Impact effect criteria ranges defined as:
      - $Low: \alpha < t_{ij} \leq average(t_{ij} > \alpha)$
      - $Medium: avg(t_{ij} > \alpha) < t_{ij} \leq \frac{max(t_{ij}>\alpha)+avg(t_{ij}>\alpha)}{2}$
      - $High: \frac{max(t_{ij}>\alpha)+average(t_{ij}>\alpha)}{2} < t_{ij}$
  - Sample Impact Relationship Diagram can be seen in Figure 11.

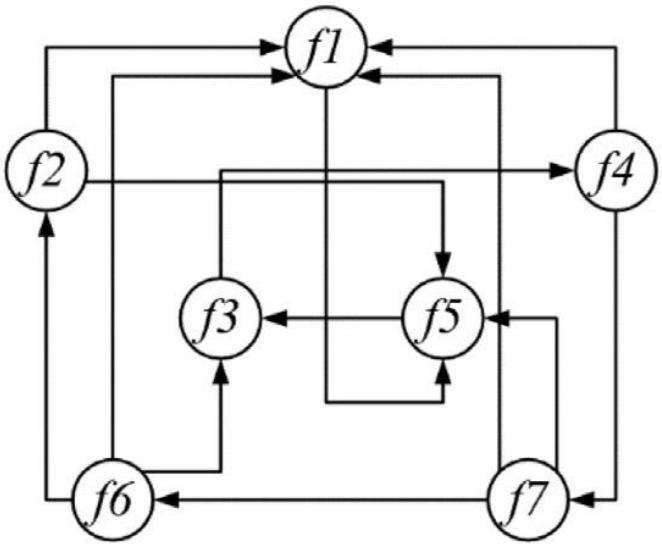


Figure 11 - Sample Impact Relationship Diagram (Du and Zhou, 2019)

For this dissertation all the data analysis for the fuzzy DEMATEL and the causal diagram were done in Microsoft Excel by using simple functions, conditional formatting and chart visualizations. The Impact relationship diagram was drawn using an online website called miro.

The same Fuzzy DEMATEL Methodology was used for studying the causes, effects and inter-relationships between the PSFs and also between the CSFs.

3.7 Ethical Considerations and Risk Management

It was really important for the author to ensure that all the data gathered in this research is gathered ethically from scientific sources that are either public or were accessed through the university provided resources. Additionally, consent was obtained for any data or photos that were gathered through the interviews, surveys and/or other discussions. Trust is the foundation of ethical research and thus the dignity and well-being of individuals participating in research must be a central concern of each person involved in the research project.

Research risk is the probability that the research subject suffers some harm as an immediate or late consequence of the study. The potential risk or harm of this research includes an invasion of privacy or breach of confidentiality.

It is the obligation of the researcher to limit access to the personal, identifiable information or financial data of the research participants and their respective companies and organizations. All the consequences of the research and risk were thoroughly expressed and discussed with all the participating subject matter experts, and it was decided and agreed that ethical and legal concerns about confidentiality can easily be resolved by keeping the names and positions for the subject matter experts were kept anonymous and that survey data collection shall be through only anonymous data by not requesting the survey participants to mention personal and identifiable information.

CHAPTER IV: DATA ANALYSIS AND RESULTS DISCUSSION

4.1 Introduction

Potential Critical Success Factors were developed through a thorough literature review on the Offsite Modular Construction. BUiD library resources and google scholar were used to find relevant articles and studies to identify potential variables and factors that would affect the offsite modular construction, and then consultations will be held with industry Subject Matter Experts who are practitioners working in different roles but with very relevant and hands-on experience on the implementation of Offsite Modular construction. A few subject matter experts were consulted and have given their valued input for this research and have helped in narrowing down the potential critical success factors to suit the local UAE projects. After gathering potential factors, these factors were discussed with 7 different experts, and it was decided that the factors listed in table 5 are suitable potential factors.

Once started on the interviews and workshops for gathering the data for the DEMATEL questionnaire, it was noticed that finding the cause and effect between 25 different factors is not very practical. So the next step was deciding to reduce the number of factors to consider for the DEMATEL questionnaire, to do so it was decided that the most suitable approach was to survey and group the factors into principal success factors (PSFs). Finding the PSFs is a widely followed approach as can be seen from research done by Kiani Mavi and Standing (2018), Wuni et al (2020a) and Wuni and Shen (2022).

A DEMATEL data analysis was additionally done for the 25 CSFs by collecting the data in a workshop meeting with only 3 experts and filling one combined survey collaboratively.

4.2 Finding and Ranking the Critical and Principal Success Factors

4.2.1 Data Collection

Collecting the data for ranking the CSFs and PSFs was done through a Questionnaire that has been designed with close-ended questions to measure and identify the significance of the variables and factors that are going to be found. The Questionnaire was also tested with the Subject Matter Experts to assure that the survey questionnaire is relevant and designed properly.

The Questionnaire was then floated to construction professionals (mainly in the UAE with a few participants working in other GCC), the data gathered was filtered to keep only the valid responses, the goal was to gather the data from different professionals who were thankfully working in different agencies, like consulting firms, construction contractors, clients, and government authorities. Additionally, the target was to gather the data from different professionals with different experiences and backgrounds, like Project Managers, Architects, MEP Engineers, Designers, Structural Engineers, Cost Consultants, etc. this allowed us to gather the opinions and perspectives of different people with different experiences and priorities.

The questionnaire was sent to targeted professionals that had different experiences in the GCC region and the use of modular offsite construction methods, due to this not being a very common practice in the UAE, data was only gathered from 45 professionals, Table 8 and figures 12 – 15 show the breakdown for the participants backgrounds.

Table 8 - Background of Respondents

Attribute	Sub-Attribute	Resp.	Resp. %
Company	Contracting/ Construction Company	35	78%

	Consultancy/ Engineering Firm	6	13%
	Developer/ Client	3	7%
	Supplier/ Logistics Firm	0	0%
	Gov. Agency/ Regulatory Authority	1	2%
Occupation of respondent	Project Manager or Construction Manager (Civil/ Architect/ MEP)	9	20%
	Site or Project Engineer (Civil/ Architect/ MEP)	4	9%
	Engineering/ Design/ Technical Manager (Civil/ Architect/ BIM)	6	13%
	Designer/ Technical Engineer (Civil/ Architect/ BIM)	7	16%
	Engineering/ Design/ Technical Manager (MEP)	9	20%
	Designer/ Technical Engineer (MEP)	4	9%
	Quantity Surveyor, Planner, Cost Control or Tendering	4	9%
	Procurement Officer/ Engineer/ Manager	2	4%
	Modular Fabricator/ Engineer/ Manufacturer	0	0%
Overall Experience	1 - 5 years	4	9%
	6 - 10 years	13	29%
	11 - 15 years	15	33%
	16 - 20 years	9	20%
	21+ years	4	9%
Modular/ Offsite Experience	0 - 1 year	8	18%
	2 years	12	27%
	3 years	7	16%
	4 years	5	11%
	5+ years	13	29%

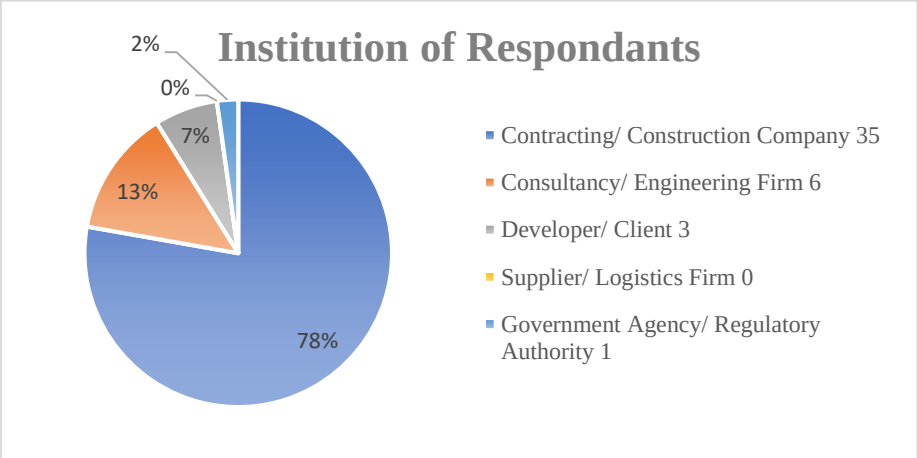


Figure 12 - Institution of Respondents

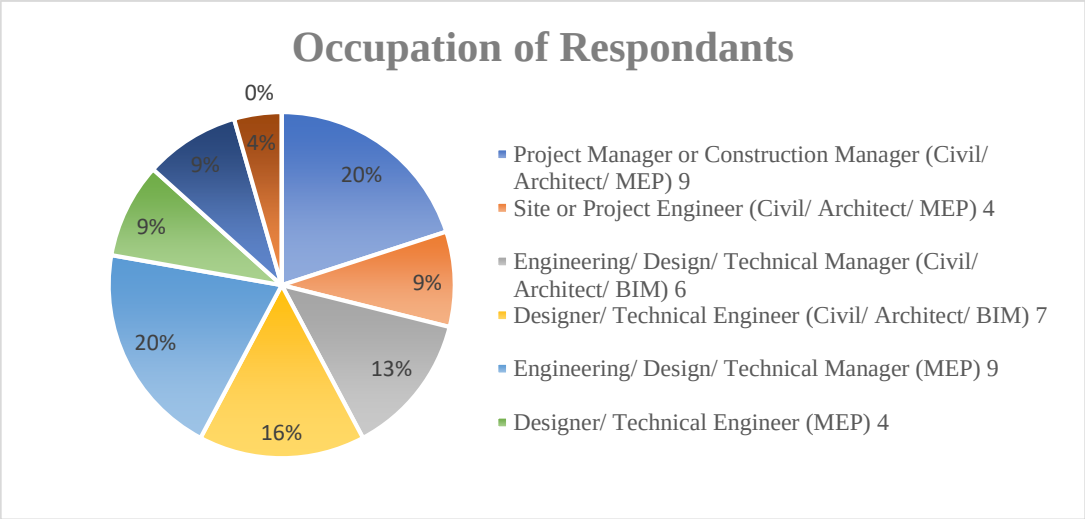


Figure 13- Occupation of Respondents

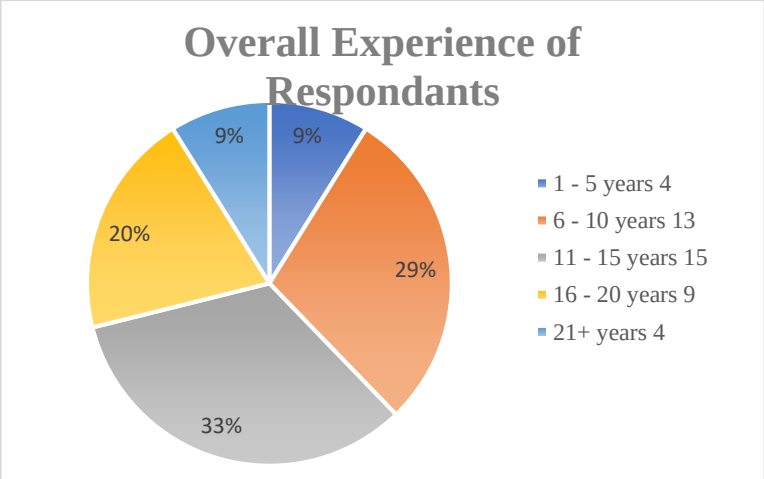


Figure 14 - Overall Experience of Respondents

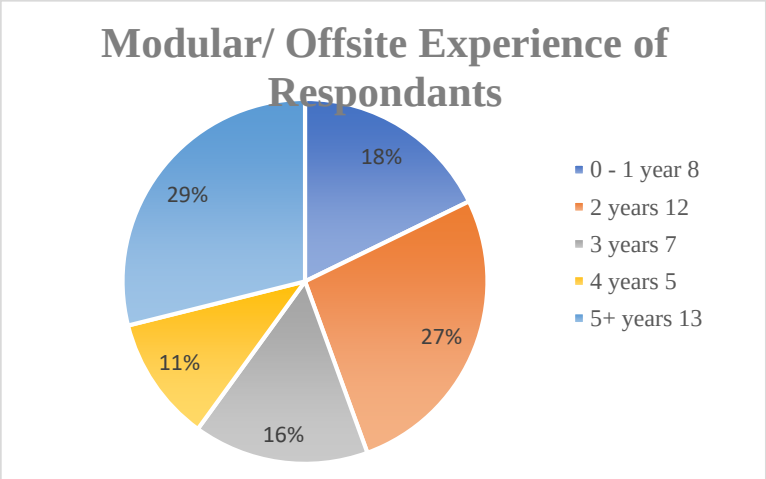


Figure 15 - Modular/ Offsite Experience of respondents

4.2.2 CSF Analysis

Statistical Analysis for the Questionnaire was done by Microsoft Excel, the questionnaire was sent to experienced professionals. As shown in table 6, 44 professionals participated with 62% of the participants having more than 10 years of overall experience and 82% having more than 2 years of experience in implementing Modular Offsite methods in local projects. The Participants were asked to rate the importance/ criticality of each of the potential factors (listed in table 5) on a scale of 1 – 5, with 1 representing Not Import at all, and 5 representing Extremely Important. A summary of the results can be seen in figure 16. More details about the questionnaire are available in Appendix A.

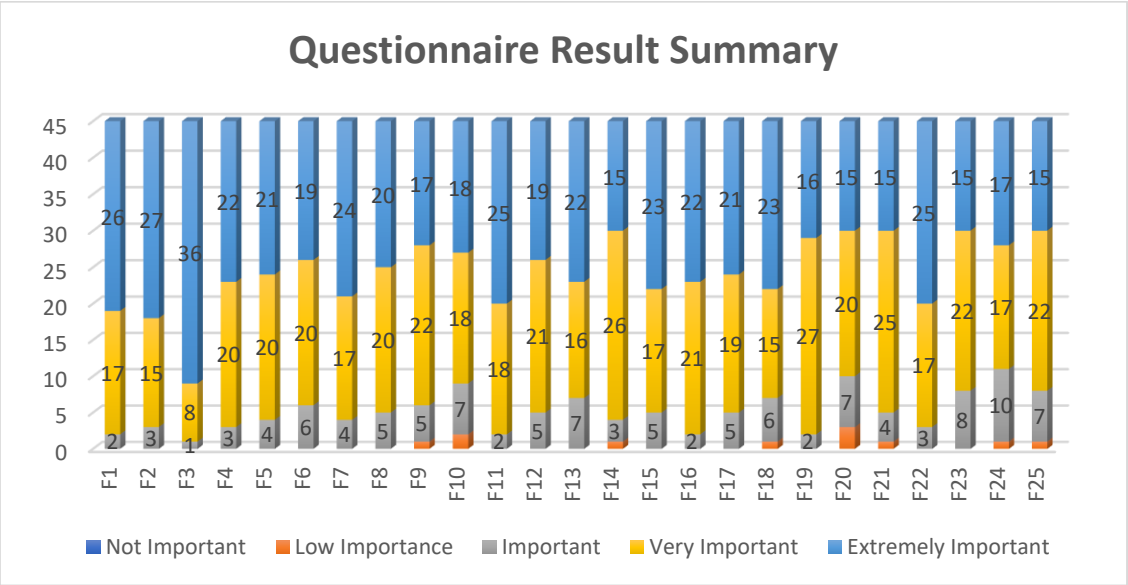


Figure 16 - Questionnaire Result Summary

The mean scoring method was performed for calculating the average ratings for the potential factors. The mean score for each factor was calculated via the below formula:

$$Mean\ Score\ (MS) = \frac{\sum(Score * Count)}{Number\ of\ Participants}$$

Once the data analysis for this section was performed, the factors were ranked based on their criticality and thus the Critical Success Factors sequence was created. A Summary of the results is shown in Table 9.

Table 9 - CSF Analysis Summary

CSF No.	CSF	Mean Score	Fuzzy Average
CSF1	Good Communication and Collaboration between all stakeholders	4.778	0.6340
CSF2	Fabricator Experience in Modules	4.533	0.5911
CSF3	Robust drawing specifications and early design freeze	4.533	0.5905
CSF4	Early Advice from Experts and Professionals	4.511	0.5873
CSF5	Effective Use of IT Resources (e.g. BIM)	4.489	0.5828
CSF6	Experience and Knowledge of Key players	4.444	0.5757
CSF7	Precise project planning and control	4.444	0.5745
CSF8	Standardization for mass production	4.422	0.5713
CSF9	On-site and Off-site Coordination	4.400	0.5662
CSF10	Supply Chain Coordination and Control	4.378	0.5630
CSF11	Alignment of Modules and Project Requirements	4.356	0.5585
CSF12	Manpower and Technicians' Experience	4.333	0.5547
CSF13	Continuous Improvement	4.333	0.5542
CSF14	Early Economic Analysis & Scope Definition	4.333	0.5535
CSF15	Suitable Procurement and Contracting Strategies	4.311	0.5526
CSF16	Availability of Local transportation infrastructure	4.311	0.5509
CSF17	Availability of Key members at the earliest stages	4.289	0.5464
CSF18	Effective coordination and management of stakeholders	4.222	0.5363
CSF19	Early Involvement of Suppliers and Fabricators	4.222	0.5352
CSF20	Appreciation of the Impact of Early Decisions	4.200	0.5318
CSF21	Supply Chain Risk Management	4.156	0.5221
CSF22	Availability of Skilled Technicians and supervisors	4.156	0.5213
CSF23	Consideration of Module Limitations	4.133	0.5185
CSF24	Early completion and cost savings recognition	4.111	0.5130
CSF25	Top Management Support and Involvement in Decision Making	4.044	0.5007

4.2.3 PSF Analysis

In order to find the PSFs criteria and the CSF grouping, the affinity diagram methodology was used, this method has been previously used by in multiple researchers including Awasthi and Chauhan (2012) who used this method along with AHP multi criteria

decision making for helping in selecting sustainable logistics initiative for cities and Han and Deng (2018) who have used the affinity diagram method in addition to DEMATEL for optimizing the CSFs for high-risk emergency systems.

After a lengthy workshop meeting along with 3 experts and after a few rounds of using the affinity diagram method, it was decided to try to group the CSFs by basing the groups on the international project management standards (figure 18) and the experts experiences and finally it was concluded to divide the CSFs into the 7 different Principal Factors, figure 17 summarizes listed principal factors:

- PF1 - Project Coordination & Quality Management : F3, F22, F15, F18
- PF2 - Cost Control & Management : F13, F24, F21
- PF3 – Design & Specification Control & Management : F4, F17, F25, F2
- PF4 - Procurement Control : F5, F19, F12, F23
- PF5 - Schedule Planning and Stakeholder Management : F14, F20, F7
- PF6 - Early Commitment & Engagement : F11, F6, F9
- PF7 - Human Resources Management : F1, F16, F8, F10

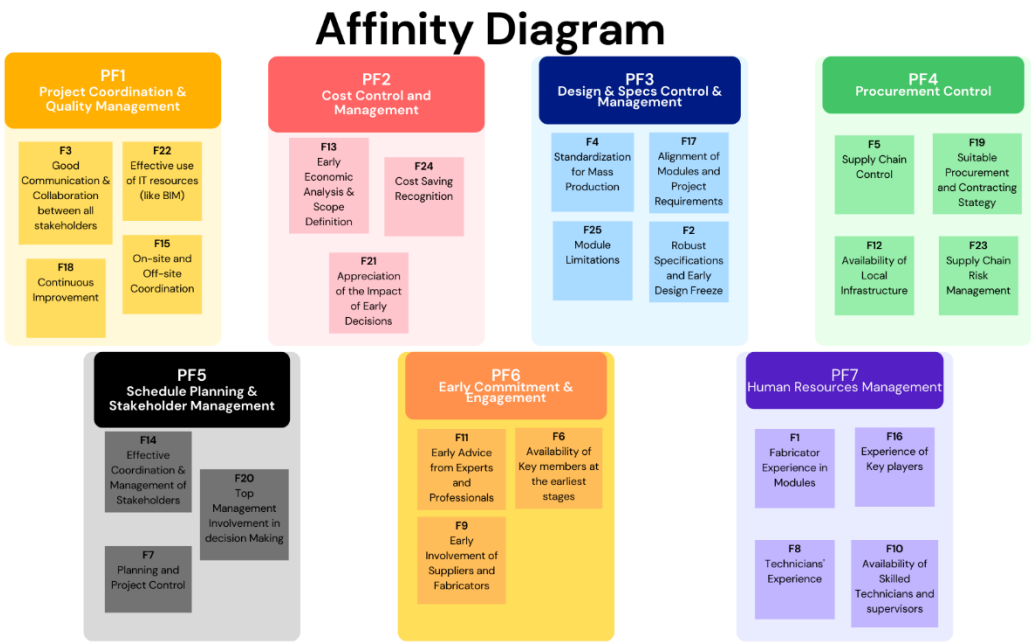


Figure 17 - PSF Workshop Affinity Diagram

Knowledge Areas	Project Management Process Groups				
	Initiating Process Group	Planning Process Group	Executing Process Group	Monitoring and Controlling Process Group	Closing Process Group
4. Project Integration Management	4.1 Develop Project Charter	4.2 Develop Project Management Plan	4.3 Direct and Manage Project Work 4.4 Manage Project Knowledge	4.5 Monitor and Control Project Work 4.6 Perform Integrated Change Control	4.7 Close Project or Phase
5. Project Scope Management		5.1 Plan Scope Management 5.2 Collect Requirements 5.3 Define Scope 5.4 Create WBS		5.5 Validate Scope 5.6 Control Scope	
6. Project Schedule Management		6.1 Plan Schedule Management 6.2 Define Activities 6.3 Sequence Activities 6.4 Estimate Activity Durations 6.5 Develop Schedule		6.6 Control Schedule	
7. Project Cost Management		7.1 Plan Cost Management 7.2 Estimate Costs 7.3 Determine Budget		7.4 Control Costs	
8. Project Quality Management		8.1 Plan Quality Management	8.2 Manage Quality	8.3 Control Quality	
9. Project Resource Management		9.1 Plan Resource Management 9.2 Estimate Activity Resources	9.3 Acquire Resources 9.4 Develop Team 9.5 Manage Team	9.6 Control Resources	
10. Project Communications Management		10.1 Plan Communications Management	10.2 Manage Communications	10.3 Monitor Communications	
11. Project Risk Management		11.1 Plan Risk Management 11.2 Identify Risks 11.3 Perform Qualitative Risk Analysis 11.4 Perform Quantitative Risk Analysis 11.5 Plan Risk Responses	11.6 Implement Risk Responses	11.7 Monitor Risks	
12. Project Procurement Management		12.1 Plan Procurement Management	12.2 Conduct Procurements	12.3 Control Procurements	
13. Project Stakeholder Management	13.1 Identify Stakeholders	13.2 Plan Stakeholder Engagement	13.3 Manage Stakeholder Engagement	13.4 Monitor Stakeholder Engagement	

Figure 18 - "Project Management Process Groups" (Project Management Institute, 2017)

To be able to rank the PSFs, the total Mean Scoring and Total Fuzzy Average score were calculated for each PSF by adding up the score of each CSF from table 9. The PSFs were then ranked, and number based on their criticality and importance which was found from the total scores. A summary of this step is shown in table 10 and Figure 19.

Table 10 - PSFs Analysis Summary

CSF/ PSF No.	CSF/ PSF	CSF Mean Score	CSF Fuzzy Average	Total PSF Mean Score	Total PSF Fuzzy Average
PSF1	**Project Coordination & Quality Management**			**18.000**	**2.337**
CSF1	Good Communication and Collaboration between all stakeholders	4.778	0.6340		
CSF5	Effective Use of IT Resources (e.g. BIM)	4.489	0.5828		
CSF9	On-site and Off-site Coordination	4.400	0.5662		

CSF/ PSF No.	CSF/ PSF	CSF Mean Score	CSF Fuzzy Average	Total PSF Mean Score	Total PSF Fuzzy Average
CSF13	Continuous Improvement	4.333	0.5542		
PSF2	**Human Resources Management**			**17.467**	**2.2429**
CSF2	Fabricator Experience in Modules	4.533	0.5911		
CSF6	Experience and Knowledge of Key players	4.444	0.5757		
CSF12	Manpower and Technicians' Experience	4.333	0.5547		
CSF22	Availability of Skilled Technicians and supervisors	4.156	0.5213		
PSF3	**Design & Specification Control & Management**			**17.444**	**2.2389**
CSF3	Robust drawing specifications and early design freeze	4.533	0.5905		
CSF8	Standardization for mass production	4.422	0.5713		
CSF11	Alignment of Modules and Project Requirements	4.356	0.5585		
CSF23	Consideration of Module Limitations	4.133	0.5185		
PSF4	**Procurement Control**			**17.156**	**2.1886**
CSF10	Supply Chain Coordination and Control	4.378	0.5630		
CSF15	Suitable Procurement and Contracting Strategies	4.311	0.5526		
CSF16	Availability of Local transportation infrastructure	4.311	0.5509		
CSF21	Supply Chain Risk Management	4.156	0.5221		
PSF5	**Early Commitment & Engagement**			**13.022**	**1.669**
CSF4	Early Advice from Experts and Professionals	4.511	0.5873		
CSF17	Availability of Key members at the earliest stages	4.289	0.5464		
CSF19	Early Involvement of Suppliers and Fabricators	4.222	0.5352		
PSF6	**Schedule Planning & Stakeholder Management**			**12.711**	**1.6116**
CSF7	Precise project planning and control	4.444	0.5745		
CSF18	Effective coordination and management of stakeholders	4.222	0.5363		
CSF25	Top Management Support and Involvement in Decision Making	4.044	0.5007		
PSF7	**Cost Control & Management**			**12.644**	**1.5983**
CSF14	Early Economic Analysis & Scope Definition	4.333	0.5535		
CSF20	Appreciation of the Impact of Early Decisions	4.200	0.5318		
CSF24	Early completion and cost savings recognition	4.111	0.5130		

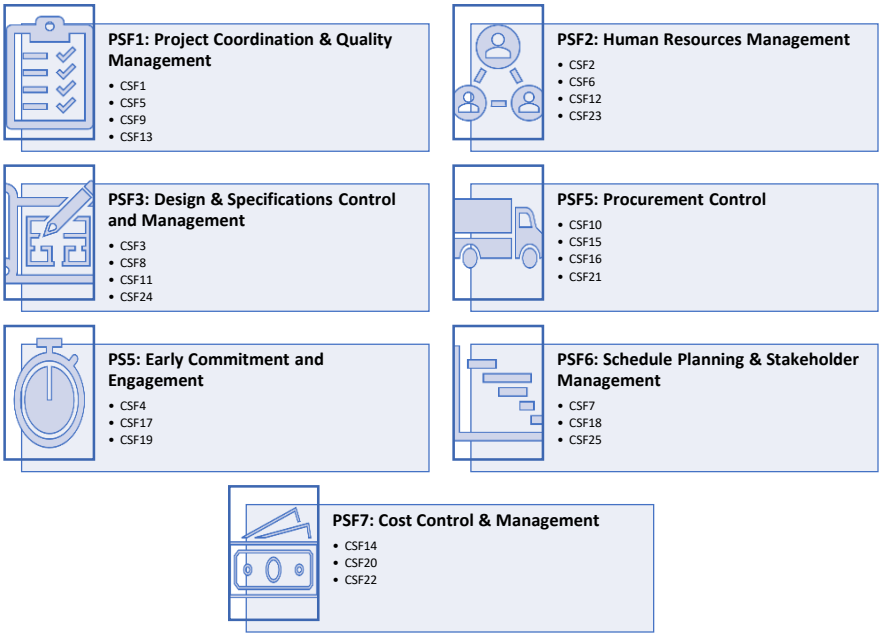


Figure 19 - PSFs Summary

4.1.3 PSF Results Discussion

The results gathered from the questionnaire have ranked the critical and principal success factors in terms of how critical these factors are, the result from the gathered data makes sense as projects involving modular construction techniques usually involve more teams which is what may make coordination, resource management, design and supply chain more highly rated on this list as the results showed that their ratings are close to each other.

However, it is worth noting here that these results do not provide enough information for project managers and professional to make decisions as these results alone do not show the relationship between the different factors, which is why it was very crucial to take these factors and do further data gathering and analysis using the DEMATEL Technique to give more insight to ease decision making.

4.3 Finding the Cause/ Effect relationships for PSFs

4.3.1 Fuzzy DEMATEL for PSFs

The experts' team consulted in this research consisted of the following 9 different experts: 2 Engineering Managers, 2 Project Managers, 2 Senior Design Engineers, 1 Factory manager, 1 Factory Technical Engineer and 1 Planning Engineer. Previous researchers have gathered data from a similar number of experts like Lin (2013), Qi et al (2020) and Du and Zhou (2019) who consulted 8 experts, 10 experts and 5 experts respectively.

The experts were then consulted to find the cause, effect, and relationship between the PSFs found in table 10. Several meetings were held with different groups of experts to provide background, to allow for brainstorming and to ensure all the experts are on the same page when it comes to the DEMATEL method, the experts were encouraged to discuss their opinions, but they were asked to fill the questionnaire separately to ensure the data gathered reflect their opinions.

The questionnaire was handed over to them and they were asked to take their time to thoroughly think prior to providing their opinion on the impact/ influence of each PSF on the other. The experts were asked to rate each item based on a scale of 1 to 5, with 1 representing "No Influence" and 5 representing "Very High Influence". The questionnaire and the experts' answers can be seen in Appendix B.

After gathering the data, Microsoft Excel was used to analyze the data. each response went through the process of "de-fuzzification" to find the crisp values for each respondent, these crisp values were then taken into consideration for the DEMATEL process to first find the M-Matrix and then after further processing to find the following matrices:

$$M\ matrix = \begin{bmatrix} 0 & 0.3936 & 0.6659 & 0.5825 & 0.5410 & 0.5819 & 0.5415 \\ 0.5830 & 0 & 0.4996 & 0.3741 & 0.5201 & 0.5185 & 0.4585 \\ 0.6662 & 0.3113 & 0 & 0.7077 & 0.6234 & 0.6025 & 0.6651 \\ 0.4778 & 0.2692 & 0.5200 & 0 & 0.6036 & 0.5399 & 0.7498 \\ 0.5409 & 0.4964 & 0.6666 & 0.5404 & 0 & 0.5608 & 0.3965 \\ 0.5619 & 0.5179 & 0.6255 & 0.6245 & 0.5203 & 0 & 0.4585 \\ 0.3104 & 0.3101 & 0.5408 & 0.5408 & 0.3114 & 0.4355 & 0 \end{bmatrix}$$

$$X\ matrix = \begin{bmatrix} 0 & 0.1101 & 0.1862 & 0.1629 & 0.1513 & 0.1627 & 0.1514 \\ 0.1630 & 0 & 0.1397 & 0.1046 & 0.1454 & 0.1450 & 0.1282 \\ 0.1863 & 0.0870 & 0 & 0.1979 & 0.1743 & 0.1685 & 0.1860 \\ 0.1336 & 0.0753 & 0.1454 & 0 & 0.1688 & 0.1510 & 0.2097 \\ 0.1512 & 0.1388 & 0.1864 & 0.1511 & 0 & 0.1568 & 0.1109 \\ 0.1571 & 0.1448 & 0.1749 & 0.1743 & 0.1455 & 0 & 0.1282 \\ 0.0868 & 0.0867 & 0.1284 & 0.1512 & 0.0871 & 0.1218 & 0 \end{bmatrix}$$

$$T\ matrix = \begin{bmatrix} 0.9444 & 0.8131 & 1.1850 & 1.1638 & 1.0757 & 1.1153 & 1.1253 \\ 0.9555 & 0.6478 & 1.0528 & 1.0200 & 0.9807 & 1.0090 & 1.0098 \\ 1.1605 & 0.8411 & 1.0939 & 1.2558 & 1.1527 & 1.1819 & 1.2156 \\ 1.0091 & 0.7482 & 1.0996 & 0.9696 & 1.0361 & 1.0537 & 1.1162 \\ 1.0574 & 0.8210 & 1.1635 & 1.1319 & 0.9253 & 1.0905 & 1.0724 \\ 1.0828 & 0.8416 & 1.1783 & 1.1729 & 1.0739 & 0.9773 & 1.1095 \\ 0.7806 & 0.6086 & 0.8741 & 0.8899 & 0.7815 & 0.8311 & 0.7386 \end{bmatrix}$$

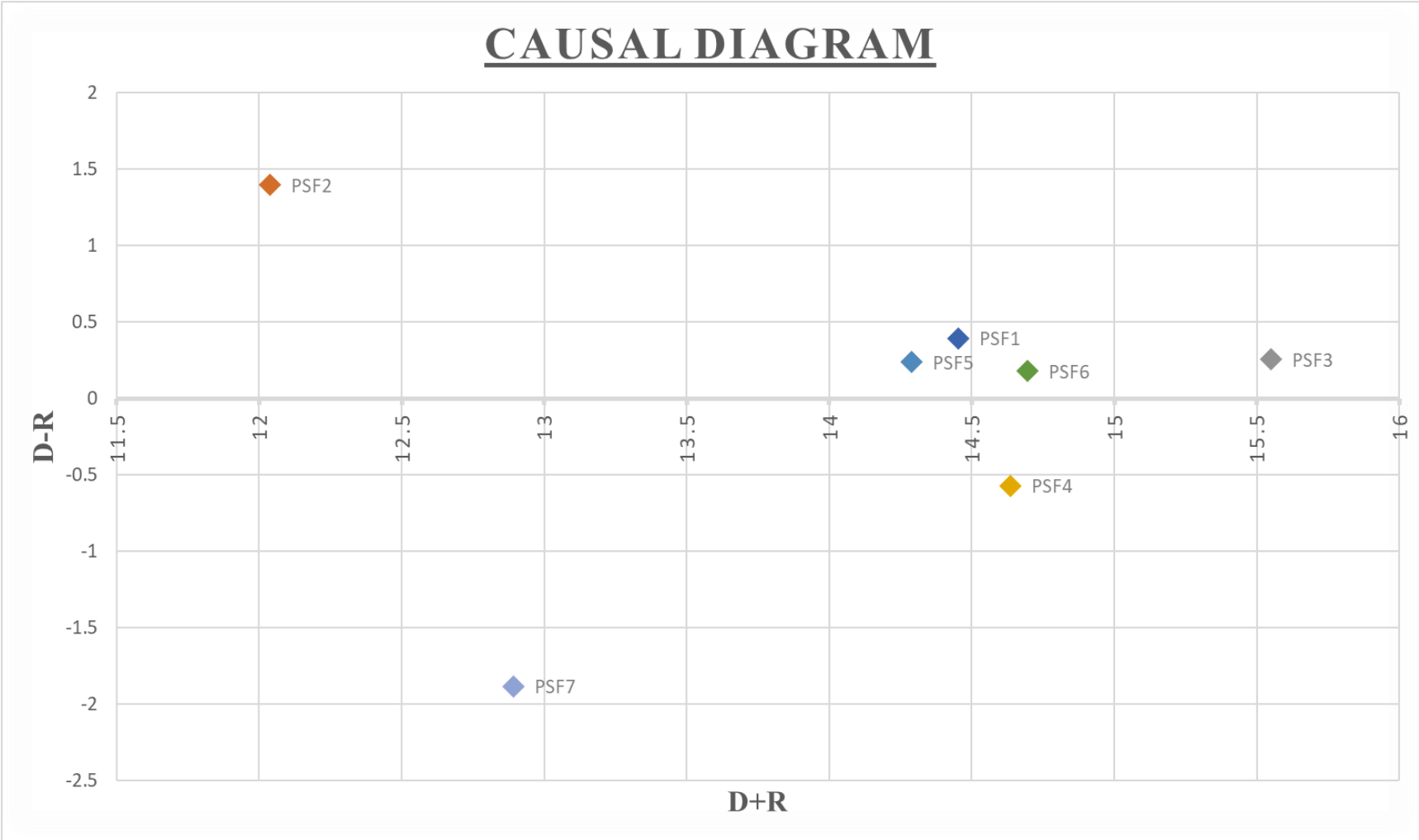
The D Value (Sum of Rows) and R Value (Sum of Columns) were then calculated, and the results were:

$$\begin{aligned} D_{PSF1} &= 7.4225 & R_{PSF1} &= 7.0303 \\ D_{PSF2} &= 6.7155 & R_{PSF2} &= 5.3213 \\ D_{PSF3} &= 7.9014 & R_{PSF3} &= 7.6472 \\ D_{PSF4} &= 7.0323 & R_{PSF4} &= 7.6038 \\ D_{PSF5} &= 7.2620 & R_{PSF5} &= 7.0257 \\ D_{PSF6} &= 7.4362 & R_{PSF6} &= 7.2588 \\ D_{PSF7} &= 5.5045 & R_{PSF7} &= 7.3872 \end{aligned}$$

After getting the D and R Values, the Influence (D+R) and Relationship (D-R) Values to find and prepare the Causal Diagrams. Table 11 summarize the influence and relationship values, and Figure 20 is the Causal Diagram which is the graphical representation of table 11.

Table 11 - Influence & Relationship Values Summary for PSFs

Factor No.	CSF Description	D	R	D+R	D-R	Remarks
PSF1	Project Coordination & Quality Management	7.4225	7.0303	14.4528	0.3921	**CAUSE**
PSF2	Human Resources Management	6.7155	5.3213	12.0368	1.3943	**CAUSE**
PSF3	Design & Specification Control & Management	7.9014	7.6472	15.5486	0.2541	**CAUSE**
PSF4	Procurement Control	7.0323	7.6038	14.6362	-0.5715	**EFFECT**
PSF5	Early Commitment & Engagement	7.2620	7.0257	14.2878	0.2363	**CAUSE**
PSF6	Schedule Planning & Stakeholder Management	7.4362	7.2588	14.6950	0.1775	**CAUSE**
PSF7	Cost Control & Management	5.5045	7.3872	12.8917	-1.8827	**EFFECT**



PSF1	Project Coordination & Quality Management	**PSF2**	Human Resources Management	**PSF3**	Design & Specification Control & Management	**PSF4**	Procurement Control	**PSF5**	Early Commitment & Engagement	**PSF6**	Schedule Planning & Stakeholder Management	**PSF7**	Cost Control & Management

Figure 20 - Causal Diagram for PSF

To find the impact of levels between the different factors, the threshold value and the impact levels between the different factors were calculated and the results were summarized as shown in Table 12. The cell colors represent the impact level, with yellow, red and green representing low impact, medium impact and high impact respectively.

Table 12 - Impact Values Summary for PSFs

	PSF1	**PSF2**	**PSF3**	**PSF4**	**PSF5**	**PSF6**	**PSF7**
PSF1	0.9444	0.8131	**1.1850**	**1.1638**	**1.0757**	**1.1153**	**1.1253**
PSF2	0.9955	0.6478	**1.0528**	**1.0200**	0.9807	**1.0090**	**1.0098**
PSF3	**1.1605**	0.8411	**1.0939**	**1.2558**	**1.1527**	**1.1819**	**1.2156**
PSF4	**1.0091**	0.7482	**1.0996**	0.9696	**1.0361**	**1.0537**	**1.1161**
PSF5	**1.0574**	0.8210	**1.1635**	**1.1319**	0.9253	**1.0905**	**1.0724**
PSF6	**1.0828**	0.8416	**1.1783**	**1.1729**	**1.0739**	0.9773	1.1095
PSF7	0.7806	0.6086	0.8741	0.8899	0.7815	0.8311	0.7386

Threshold Value (α) =	**1.006**
Low Impact Range=	**1.009 - 1.109**
Medium Impact Range=	**1.110 - 1.182**
High Impact Range=	**1.183 - 1.256**

The impact relationship diagram (Figure 21) was drawn to provide a graphical representation of table 12.

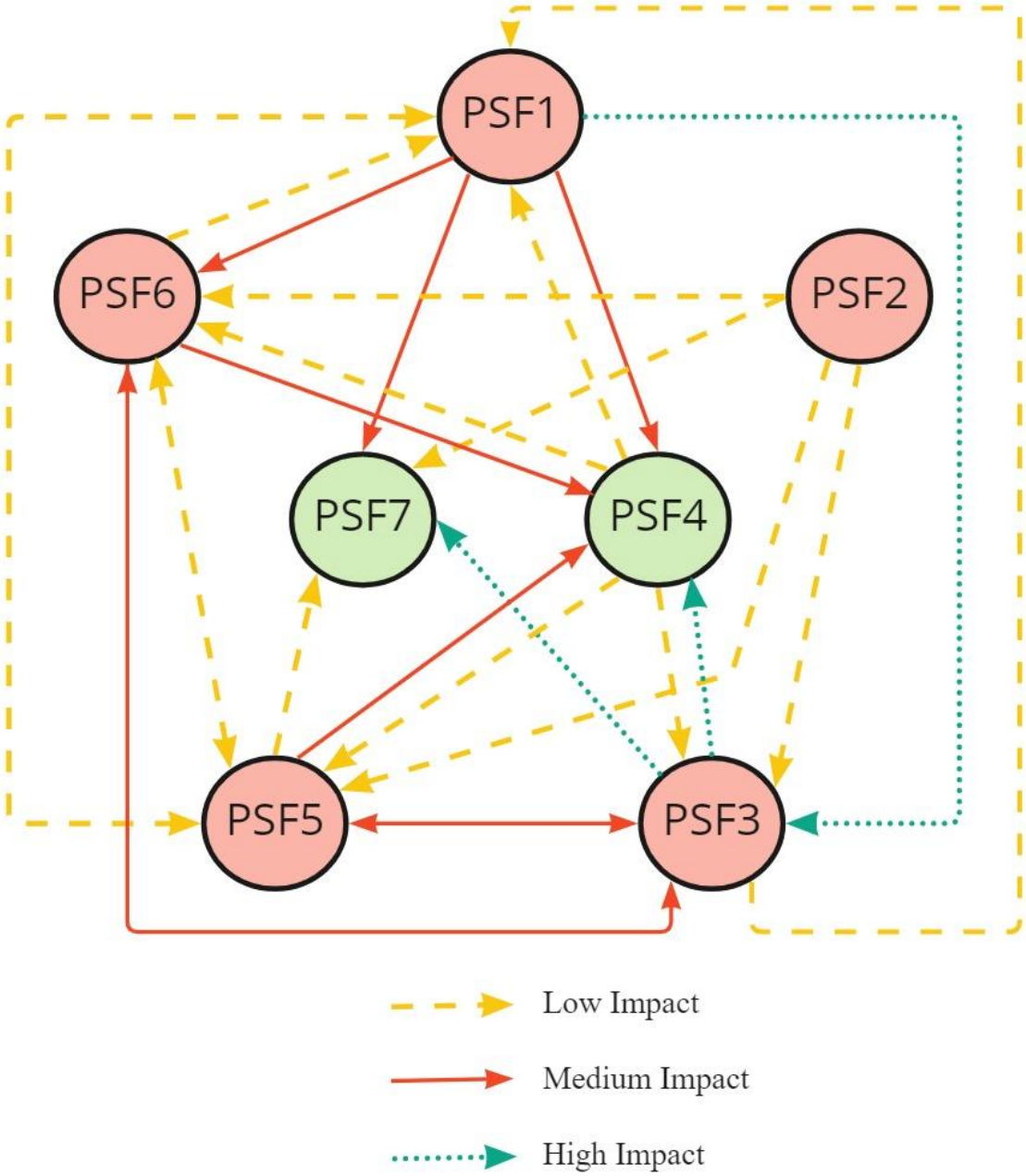


Figure 21 - Impact Relationship Diagram for PSFs

4.3.2 Fuzzy DEMATEL Results Summary for PSFs

Table 11 shows that out of the seven PSFs compared, 2 PSFs ("Procurement Control" and "Cost Control & Management") were found to be effects and the other 5 PSFs were found to be causes. The causal diagram (Figure 20) and the impact relationship diagram (Figure 21) show that PSF7 (Cost Control & Management) have no impact on any other factor and PSF2

(Human Resources Management) is not impacted by any other factor. Additionally, the other PSFs impact each other significantly. The following is a summary for the results from Tables 11 & 12 and Figures 20 & 21:

4.3.2.1. PSF1 - Project Coordination & Quality Management

D Value:	*7.4225*	R Value:	*7.0303*
D+R Value:	*14.4528*	D-R Value:	*0.3943*
Causal Effect Criteria:	*Cause*	R-D Value:	*-0.3921*

	Low Impact	Medium Impact	High Impact
Impacting:	*PSF5*	*PSF4, PSF6, PSF7*	*PSF3*
Impacted By:	*PSF4, PSF5, PSF6*	*PSF3*	-

4.2.2.2. PSF2 - Human Resources Management

D Value:	*6.7155*	R Value:	*5.3213*
D+R Value:	*12.0368*	D-R Value:	*1.3943*
Causal Effect Criteria:	*Cause*	R-D Value:	*-1.3943*

	Low Impact	Medium Impact	High Impact
Impacting:	*PSF3, PSF4, PSF6, PSF7*	-	-
Impacted By:	-	-	-

4.3.2.3. PSF3 - Design & Specification Control & Management

D Value:	*7.9014*	R Value:	*7.6472*
D+R Value:	*15.5486*	D-R Value:	*0.2541*
Causal Effect Criteria:	*Cause*	R-D Value:	*-0.2541*

	Low Impact	Medium Impact	High Impact
Impacting:	*PSF3*	*PSF1, PSF5, PSF6*	*PSF4, PSF7*
Impacted By:	*PSF2, PSF3, PSF4*	*PSF5, PSF6*	*PSF1*

4.3.2.4. PSF4 - Procurement Control

D Value:	*7.0323*	R Value:	*7.6038*
D+R Value:	*14.6362*	D-R Value:	*-0.5715*
Causal Effect Criteria:	*Effect*	R-D Value:	*0.5715*

	Low Impact	Medium Impact	High Impact
Impacting:	*PSF1, PSF3, PSF5, PSF6*	*PSF7*	-
Impacted By:	*PSF2*	*PSF1, PSF5, PSF6*	*PSF3*

4.3.2.5. PSF5 - Early Commitment & Engagement

D Value:	*7.2620*	R Value:	*7.0257*
D+R Value:	*14.2878*	D-R Value:	*0.2363*
Causal Effect Criteria:	*Cause*	R-D Value:	*-0.2363*

	Low Impact	Medium Impact	High Impact
Impacting:	*PSF1, PSF6, PSF7*	*PSF3, PSF4*	-
Impacted By:	*PSF1, PSF4, PSF6*	*PSF3*	-

4.3.2.6. PSF6 - Schedule Planning & Stakeholder Management

D Value:	*7.4362*	R Value:	*7.2588*
D+R Value:	*14.6950*	D-R Value:	*0.1775*
Causal Effect Criteria:	*Cause*	R-D Value:	*-0.1775*

	Low Impact	Medium Impact	High Impact
Impacting:	*PSF1, PSF5*	*PSF3, PSF4*	-
Impacted By:	*PSF2, PSF4, PSF5*	*PSF1, PSF3*	-

4.3.2.7. PSF7 - Cost Control & Management

D Value:	*5.5045*	R Value:	*7.3872*
D+R Value:	*12.8917*	D-R Value:	*-1.8827*
Causal Effect Criteria:	*Effect*	R-D Value:	*1.8827*

	Low Impact	Medium Impact	High Impact
Impacting:	-	-	-
Impacted By:	*PSF2, PSF5*	*PSF1, PSF4*	*PSF3*

4.3.3 Fuzzy DEMATEL Results discussion for PSFs

The results gathered from the Fuzzy DEMATEL Data Analysis summarized in Table 11, Table 12, Figure 20, Figure 21, and Section 4.3.2, indicate that:

- **Influence Criteria:**
  - Causes:
    - PSF1 – Project Coordination & Quality Management
    - PSF2 – Human Resources Management
    - PSF3 – Design & Specification Control & Management

        - PSF5 – Early Commitment & Engagement
        - PSF6 – Schedule Planning & Stakeholder Management
    - Effects:
        - PSF4 – Procurement Control
        - PSF7 – Cost Control & Management

- **Influence wise:**
    - Most Influential Factor (highest D Value):
        - PSF3 – Design & Specification Control & Management
    - Least influential factor (lowest D Value):
        - PSF7 – Cost Control & Management

- **Relationship wise:**
    - Most influenced/ Affected factor (lowest relationship factor (D-R)):
        - PSF7 – Cost Control & Management
    - Least influenced/ Affected factor (Highest relationship factor (D-R)):
        - PSF2 – Human Resources Management

These results indicate that PSF3 (Design & Specification Control & Management) is the most influential factor and PSF7 (Cost Control & Management) is the least influential factor and is having no impact on the overall implementation of offsite modular construction but is actually very highly influenced by the other factors. Tables 13 and 14 summarizes the ranking of the PSFs based on their influence and Relationship (i.e. the ranking of other factors' influence on them) respectively.

Table 13 - PSF Influence Rank

Rank	Factor No.	CSF Description	D
1	PSF3	Design & Specification Control & Management	7.9014
2	PSF6	Schedule Planning & Stakeholder Management	7.4362
3	PSF1	Project Coordination & Quality Management	7.4225
4	PSF5	Early Commitment & Engagement	7.2620
5	PSF4	Procurement Control	7.0323
6	PSF2	Human Resources Management	6.7155
7	PSF7	Cost Control & Management	5.5045

Table 14 - PSFs Relationship Rank

Rank	Factor No.	CSF Description	D-R
1	PSF7	Cost Control & Management	-1.8827
2	PSF4	Procurement Control	-0.5715
3	PSF6	Schedule Planning & Stakeholder Management	0.1775
4	PSF5	Early Commitment & Engagement	0.2363
5	PSF3	Design & Specification Control & Management	0.2541
6	PSF1	Project Coordination & Quality Management	0.3921
7	PSF2	Human Resources Management	1.3943

If the results of the first part of the research (the questionnaire survey with 45 respondents) and the results of the DEMATEL survey (with 9 respondents), there are minor differences in the rankings for PSF1, PSF3, PSF4, PSF5 and PSF7 however there is a huge difference in the rankings for PSF2 and PSF6, this difference was caused by the limited number of participants in the first survey which was sent to general professionals who were not all experts in the implementation of offsite modular construction techniques.

Additionally, the variance between both parts of the research might have been because 8 of the 9 experts consulted work in the same group of companies and only 1 is working in a different company due to the difficulty of finding subject matter experts willing to participate in this research since the 8 work in the same company they might not consider the human

resource management as a big problem because they are not facing a problem with this issue in their establishment.

4.4 Finding the Cause/ Effect relationships for CSFs

4.4.1 Fuzzy DEMATEL for CSFs

In addition to finding the causes, effects, and relationships between the PSFs, it was decided to find study the same but between the 25 CSFs and to compare these with the results found in section 4.2. As filling these surveys are really time-consuming and unfortunately not all the 9 experts had the time to participate in this part, only 3 of the experts were able to join and it was decided to have a long workshop meeting and discussion to fill one combined survey rather that everyone filling on this own to ease the process. The M, X and T matrices were found and the Influence and Relationship values were calculated and summarized in Table 15.

Table 15 - Influence and Relationship Summary for CSFs

Factor No.	CSF Description	D	R	D+R	D-R	Remarks
CSF1	Good Communication and Collaboration between all stakeholders	5.1217	4.0578	9.1794	1.0639	**CAUSE**
CSF2	Fabricator Experience in Modules	5.1110	2.3908	7.5018	2.7202	**CAUSE**
CSF3	Robust drawing specifications and early design freeze	5.6971	5.5299	11.2270	0.1671	**CAUSE**
CSF4	Early Advice from Experts and Professionals	5.3472	4.9536	10.3009	0.3936	**CAUSE**
CSF5	Effective Use of IT Resources (e.g. BIM)	4.2693	4.1614	8.4308	0.1079	**CAUSE**
CSF6	Experience and Knowledge of Key players	6.0269	2.7045	8.7314	3.3224	**CAUSE**
CSF7	Precise project planning and control	6.1908	5.9626	12.1534	0.2283	**CAUSE**
CSF8	Standardization for mass production	4.6783	4.8048	9.4832	-0.1265	**EFFECT**
CSF9	On-site and Off-site Coordination	5.6281	5.3057	10.9338	0.3224	**CAUSE**

Factor No.	CSF Description	D	R	D+R	D-R	Remarks
CSF10	Supply Chain Coordination and Control	3.0640	7.0560	10.1200	-3.9921	**EFFECT**
CSF11	Alignment of Modules and Project Requirements	4.8398	5.0031	9.8429	-0.1633	**EFFECT**
CSF12	Manpower and Technicians' Experience	4.9462	2.1229	7.0692	2.8233	**CAUSE**
CSF13	Continuous Improvement	4.9496	6.2446	11.1942	-1.2950	**EFFECT**
CSF14	Early Economic Analysis & Scope Definition	4.6613	6.4586	11.1200	-1.7973	**EFFECT**
CSF15	Suitable Procurement and Contracting Strategies	4.4838	7.3026	11.7864	-2.8188	**EFFECT**
CSF16	Availability of Local transportation infrastructure	3.3930	1.3861	4.7790	2.0069	**CAUSE**
CSF17	Availability of Key members at the earliest stages	5.1242	3.0248	8.1490	2.0994	**CAUSE**
CSF18	Effective coordination and management of stakeholders	3.2310	4.5944	7.8253	-1.3634	**EFFECT**
CSF19	Early Involvement of Suppliers and Fabricators	4.9905	4.6925	9.6830	0.2981	**CAUSE**
CSF20	Appreciation of the Impact of Early Decisions	4.6833	6.2505	10.9337	-1.5672	**EFFECT**
CSF21	Supply Chain Risk Management	3.7396	6.5980	10.3376	-2.8584	**EFFECT**
CSF22	Availability of Skilled Technicians and supervisors	4.1351	2.9621	7.0972	1.1730	**CAUSE**
CSF23	Consideration of Module Limitations	4.4053	4.1899	8.5951	0.2154	**CAUSE**
CSF24	Early completion and cost savings recognition	3.7074	6.9948	10.7023	-3.2874	**EFFECT**
CSF25	Top Management Support and Involvement in Decision Making	5.9906	3.6630	9.6536	2.3276	**CAUSE**

From the results of table 15, eventually the causal diagram (figure 22) and impact relationship summary (table 16).

M-Matrix =

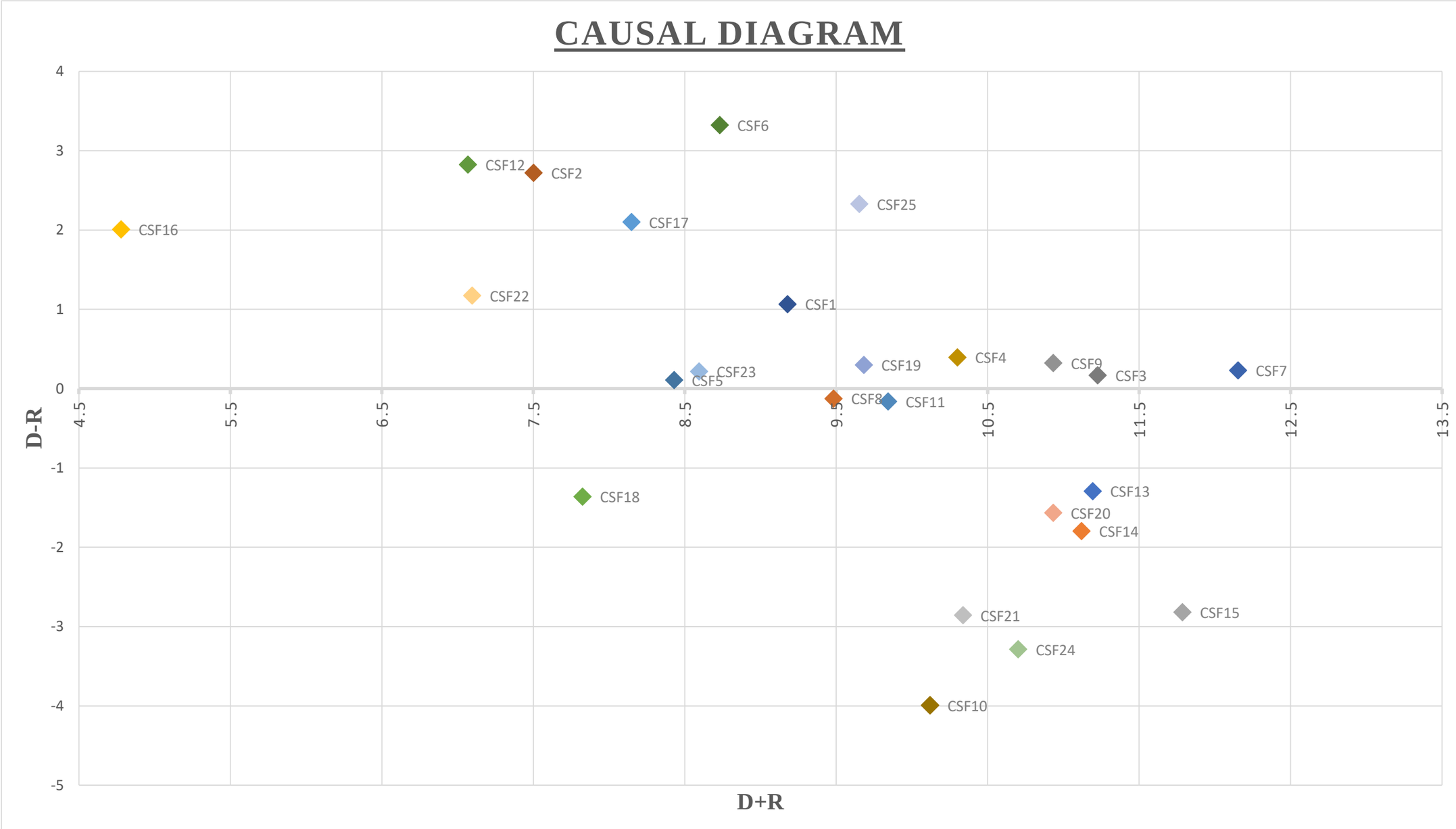
0.0000	0.3040	0.8748	0.5000	0.4972	0.3084	0.8748	0.6905	0.8748	0.5000	0.5000	0.1277	0.6905	0.3095	0.5000	0.1217	0.1262	0.8748	0.1252	0.1252	0.5000	0.1252	0.3084	0.3095	0.6860
0.4972	0.0000	0.5000	0.8748	0.3084	0.3084	0.5000	0.6905	0.5000	0.3095	0.6905	0.3040	0.8748	0.3095	0.5000	0.1217	0.3084	0.5000	0.1252	0.3095	0.5000	0.6905	0.6860	0.5000	0.1262
0.3084	0.1277	0.0000	0.3095	0.4972	0.1262	0.8748	0.8748	0.8748	0.6905	0.6905	0.1277	0.8748	0.8748	0.6905	0.1217	0.1262	0.5000	0.5000	0.6905	0.5000	0.1252	0.6860	0.6905	0.4972
0.3084	0.3040	0.6905	0.0000	0.6860	0.3084	0.3095	0.5000	0.5000	0.6905	0.6905	0.1277	0.5000	0.6905	0.6905	0.1217	0.3084	0.6905	0.6905	0.5000	0.5000	0.3095	0.6860	0.6905	0.3084
0.4972	0.1277	0.6905	0.1252	0.0000	0.1262	0.6905	0.6905	0.6905	0.1252	0.3095	0.1277	0.5000	0.6905	0.5000	0.1217	0.3084	0.1252	0.1252	0.6905	0.3095	0.1252	0.4972	0.6905	0.1262
0.6860	0.4879	0.6905	0.5000	0.6860	0.0000	0.6905	0.5000	0.6905	0.6905	0.6905	0.3040	0.6905	0.6905	0.6905	0.1217	0.4972	0.6905	0.1252	0.6905	0.6905	0.1252	0.4972	0.6905	0.3084
0.3084	0.3040	0.3095	0.6905	0.3084	0.3084	0.0000	0.5000	0.6905	0.8748	0.5000	0.3040	0.8748	0.8748	0.8748	0.1217	0.6860	0.6905	0.8748	0.8748	0.6905	0.3095	0.3084	0.8748	0.4972
0.1262	0.1277	0.8748	0.3095	0.3084	0.3084	0.6905	0.0000	0.3095	0.5000	0.8748	0.1277	0.6905	0.6905	0.6905	0.1217	0.1262	0.3095	0.1252	0.6905	0.6905	0.1252	0.4972	0.6905	0.1262
0.6860	0.3040	0.6905	0.5000	0.4972	0.3084	0.6905	0.5000	0.0000	0.8748	0.5000	0.1277	0.8748	0.3095	0.8748	0.1217	0.1262	0.8748	0.5000	0.6905	0.6905	0.1252	0.3084	0.6905	0.4972
0.3084	0.1277	0.1252	0.5000	0.3084	0.1262	0.3095	0.1252	0.3095	0.0000	0.1252	0.1277	0.3095	0.1252	0.6905	0.1217	0.1262	0.3095	0.3095	0.3095	0.8748	0.1252	0.3084	0.5000	0.1262
0.1262	0.1277	0.6905	0.1252	0.4972	0.1262	0.6905	0.8748	0.6905	0.6905	0.0000	0.1277	0.6905	0.5000	0.8748	0.1217	0.1262	0.1252	0.3095	0.6905	0.6905	0.1252	0.4972	0.6905	0.3084
0.3084	0.4879	0.3095	0.6905	0.3084	0.6860	0.3095	0.3095	0.3095	0.3095	0.1252	0.0000	0.8748	0.5000	0.5000	0.1217	0.4972	0.3095	0.5000	0.6905	0.3095	0.5000	0.3084	0.5000	0.6860
0.6860	0.3040	0.5000	0.6905	0.3084	0.3084	0.3095	0.5000	0.5000	0.6905	0.6905	0.1277	0.0000	0.5000	0.3095	0.1217	0.3084	0.3095	0.6905	0.5000	0.5000	0.3095	0.4972	0.5000	0.4972
0.1262	0.1277	0.6905	0.5000	0.3084	0.3084	0.6905	0.3095	0.1252	0.6905	0.3095	0.1277	0.3095	0.0000	0.6905	0.1217	0.4972	0.5000	0.5000	0.8748	0.5000	0.5000	0.1262	0.6905	0.4972
0.3084	0.3040	0.3095	0.3095	0.3084	0.3084	0.5000	0.3095	0.5000	0.8748	0.3095	0.3040	0.5000	0.5000	0.0000	0.1217	0.3084	0.5000	0.5000	0.5000	0.8748	0.3095	0.3084	0.5000	0.3084
0.1262	0.1277	0.1252	0.3095	0.3084	0.1262	0.5000	0.3095	0.3095	0.6905	0.1252	0.1277	0.1252	0.3095	0.6905	0.0000	0.1262	0.1252	0.3095	0.6905	0.8748	0.1252	0.3084	0.3095	0.3084
0.4972	0.3040	0.5000	0.5000	0.4972	0.4972	0.5000	0.3095	0.5000	0.5000	0.5000	0.3040	0.5000	0.5000	0.5000	0.1217	0.0000	0.5000	0.5000	0.6905	0.5000	0.3095	0.3084	0.6905	0.4972
0.4972	0.1277	0.5000	0.1252	0.1262	0.1262	0.3095	0.1252	0.3095	0.3095	0.3095	0.1277	0.3095	0.5000	0.5000	0.1217	0.1262	0.0000	0.3095	0.5000	0.3095	0.3095	0.1262	0.5000	0.3084
0.3084	0.1277	0.5000	0.5000	0.3084	0.1262	0.5000	0.5000	0.5000	0.8748	0.6905	0.3040	0.5000	0.6905	0.6905	0.1217	0.3084	0.5000	0.0000	0.5000	0.8748	0.1252	0.4972	0.6905	0.3084
0.3084	0.1277	0.3095	0.5000	0.3084	0.1262	0.6905	0.1252	0.5000	0.6905	0.3095	0.3040	0.5000	0.8748	0.8748	0.1217	0.4972	0.3095	0.5000	0.0000	0.6905	0.3095	0.3084	0.8748	0.1262
0.3084	0.1277	0.3095	0.3095	0.3084	0.1262	0.3095	0.3095	0.3095	0.8748	0.3095	0.1277	0.5000	0.6905	0.6905	0.1217	0.1262	0.1252	0.3095	0.5000	0.0000	0.1252	0.3084	0.6905	0.3084
0.4972	0.3040	0.3095	0.3095	0.3084	0.4972	0.3095	0.6905	0.3095	0.3095	0.3095	0.4879	0.5000	0.6905	0.6905	0.1217	0.1262	0.1252	0.1252	0.6905	0.1252	0.0000	0.1262	0.5000	0.3084
0.1262	0.1277	0.6905	0.5000	0.4972	0.1262	0.6905	0.5000	0.3095	0.6905	0.6905	0.1277	0.6905	0.5000	0.6905	0.1217	0.1262	0.1252	0.3095	0.3095	0.6905	0.1252	0.0000	0.6905	0.1262
0.3084	0.1277	0.3095	0.5000	0.3084	0.1262	0.3095	0.3095	0.3095	0.5000	0.3095	0.1277	0.3095	0.6905	0.6905	0.1217	0.3084	0.1252	0.5000	0.5000	0.5000	0.3095	0.3084	0.0000	0.1262
0.6860	0.3040	0.6905	0.6905	0.3084	0.3084	0.8748	0.1252	0.6905	0.8748	0.3095	0.1277	0.6905	0.8748	0.6905	0.1217	0.1262	0.6905	0.6905	0.5000	0.6905	0.8748	0.3084	0.8748	0.0000

X-Matrix =

0.0000	0.0246	0.0707	0.0404	0.0402	0.0249	0.0707	0.0558	0.0707	0.0404	0.0404	0.0103	0.0558	0.0250	0.0404	0.0098	0.0102	0.0707	0.0101	0.0101	0.0404	0.0101	0.0249	0.0250	0.0554
0.0402	0.0000	0.0404	0.0707	0.0249	0.0249	0.0404	0.0558	0.0404	0.0250	0.0558	0.0246	0.0707	0.0250	0.0404	0.0098	0.0249	0.0404	0.0101	0.0250	0.0404	0.0558	0.0554	0.0404	0.0102
0.0249	0.0103	0.0000	0.0250	0.0402	0.0102	0.0707	0.0707	0.0707	0.0558	0.0558	0.0103	0.0707	0.0707	0.0558	0.0098	0.0102	0.0404	0.0404	0.0558	0.0404	0.0101	0.0554	0.0558	0.0402
0.0249	0.0246	0.0558	0.0000	0.0554	0.0249	0.0250	0.0404	0.0404	0.0558	0.0558	0.0103	0.0404	0.0558	0.0558	0.0098	0.0249	0.0558	0.0558	0.0404	0.0404	0.0250	0.0554	0.0558	0.0249
0.0402	0.0103	0.0558	0.0101	0.0000	0.0102	0.0558	0.0558	0.0558	0.0101	0.0250	0.0103	0.0404	0.0558	0.0404	0.0098	0.0249	0.0101	0.0101	0.0558	0.0250	0.0101	0.0402	0.0558	0.0102
0.0554	0.0394	0.0558	0.0404	0.0554	0.0000	0.0558	0.0404	0.0558	0.0558	0.0558	0.0246	0.0558	0.0558	0.0558	0.0098	0.0402	0.0558	0.0101	0.0558	0.0558	0.0101	0.0402	0.0558	0.0249
0.0249	0.0246	0.0250	0.0558	0.0249	0.0249	0.0000	0.0404	0.0558	0.0707	0.0404	0.0246	0.0707	0.0707	0.0707	0.0098	0.0554	0.0558	0.0707	0.0707	0.0558	0.0250	0.0249	0.0707	0.0402
0.0102	0.0103	0.0707	0.0250	0.0249	0.0249	0.0558	0.0000	0.0250	0.0404	0.0707	0.0103	0.0558	0.0558	0.0558	0.0098	0.0102	0.0250	0.0101	0.0558	0.0558	0.0101	0.0402	0.0558	0.0102
0.0554	0.0246	0.0558	0.0404	0.0402	0.0249	0.0558	0.0404	0.0000	0.0707	0.0404	0.0103	0.0707	0.0250	0.0707	0.0098	0.0102	0.0707	0.0404	0.0558	0.0558	0.0101	0.0249	0.0558	0.0402
0.0249	0.0103	0.0101	0.0404	0.0249	0.0102	0.0250	0.0101	0.0250	0.0000	0.0101	0.0103	0.0250	0.0101	0.0558	0.0098	0.0102	0.0250	0.0250	0.0250	0.0707	0.0101	0.0249	0.0404	0.0102
0.0102	0.0103	0.0558	0.0101	0.0402	0.0102	0.0558	0.0707	0.0558	0.0558	0.0000	0.0103	0.0558	0.0404	0.0707	0.0098	0.0102	0.0101	0.0250	0.0558	0.0558	0.0101	0.0402	0.0558	0.0249
0.0249	0.0394	0.0250	0.0558	0.0249	0.0554	0.0250	0.0250	0.0250	0.0250	0.0101	0.0000	0.0707	0.0404	0.0404	0.0098	0.0402	0.0250	0.0404	0.0558	0.0250	0.0404	0.0249	0.0404	0.0554
0.0554	0.0246	0.0404	0.0558	0.0249	0.0249	0.0250	0.0404	0.0404	0.0558	0.0558	0.0103	0.0000	0.0404	0.0250	0.0098	0.0249	0.0250	0.0558	0.0404	0.0404	0.0250	0.0402	0.0404	0.0402
0.0102	0.0103	0.0558	0.0404	0.0249	0.0249	0.0558	0.0250	0.0101	0.0558	0.0250	0.0103	0.0250	0.0000	0.0558	0.0098	0.0402	0.0404	0.0404	0.0707	0.0404	0.0404	0.0102	0.0558	0.0402
0.0249	0.0246	0.0250	0.0250	0.0249	0.0249	0.0404	0.0250	0.0404	0.0707	0.0250	0.0246	0.0404	0.0404	0.0000	0.0098	0.0249	0.0404	0.0404	0.0404	0.0707	0.0250	0.0249	0.0404	0.0249
0.0102	0.0103	0.0101	0.0250	0.0249	0.0102	0.0404	0.0250	0.0250	0.0558	0.0101	0.0103	0.0101	0.0250	0.0558	0.0000	0.0102	0.0101	0.0250	0.0558	0.0707	0.0101	0.0249	0.0250	0.0249
0.0402	0.0246	0.0404	0.0404	0.0402	0.0402	0.0404	0.0250	0.0404	0.0404	0.0404	0.0246	0.0404	0.0404	0.0404	0.0098	0.0000	0.0404	0.0404	0.0558	0.0404	0.0250	0.0249	0.0558	0.0402
0.0402	0.0103	0.0404	0.0101	0.0102	0.0102	0.0250	0.0101	0.0250	0.0250	0.0250	0.0103	0.0250	0.0404	0.0404	0.0098	0.0102	0.0000	0.0250	0.0404	0.0250	0.0250	0.0102	0.0404	0.0249
0.0249	0.0103	0.0404	0.0404	0.0249	0.0102	0.0404	0.0404	0.0404	0.0707	0.0558	0.0246	0.0404	0.0558	0.0558	0.0098	0.0249	0.0404	0.0000	0.0404	0.0707	0.0101	0.0402	0.0558	0.0249
0.0249	0.0103	0.0250	0.0404	0.0249	0.0102	0.0558	0.0101	0.0404	0.0558	0.0250	0.0246	0.0404	0.0707	0.0707	0.0098	0.0402	0.0250	0.0404	0.0000	0.0558	0.0250	0.0249	0.0707	0.0102
0.0249	0.0103	0.0250	0.0250	0.0249	0.0102	0.0250	0.0250	0.0250	0.0707	0.0250	0.0103	0.0404	0.0558	0.0558	0.0098	0.0102	0.0101	0.0250	0.0404	0.0000	0.0101	0.0249	0.0558	0.0249
0.0402	0.0246	0.0250	0.0250	0.0249	0.0402	0.0250	0.0558	0.0250	0.0250	0.0250	0.0394	0.0404	0.0558	0.0558	0.0098	0.0102	0.0101	0.0101	0.0558	0.0101	0.0000	0.0102	0.0404	0.0249
0.0102	0.0103	0.0558	0.0404	0.0402	0.0102	0.0558	0.0404	0.0250	0.0558	0.0558	0.0103	0.0558	0.0404	0.0558	0.0098	0.0102	0.0101	0.0250	0.0250	0.0558	0.0101	0.0000	0.0558	0.0102
0.0249	0.0103	0.0250	0.0404	0.0249	0.0102	0.0250	0.0250	0.0250	0.0404	0.0250	0.0103	0.0250	0.0558	0.0558	0.0098	0.0249	0.0101	0.0404	0.0404	0.0404	0.0250	0.0249	0.0000	0.0102
0.0554	0.0246	0.0558	0.0558	0.0249	0.0249	0.0707	0.0101	0.0558	0.0707	0.0250	0.0103	0.0558	0.0707	0.0558	0.0098	0.0102	0.0558	0.0558	0.0404	0.0558	0.0707	0.0249	0.0707	0.0000

T-Matrix =

$$
\begin{bmatrix}
0.1476 & 0.1094 & 0.2681 & 0.2159 & 0.1880 & 0.1201 & 0.2828 & 0.2269 & 0.2603 & 0.2946 & 0.2208 & 0.0849 & 0.2801 & 0.2578 & 0.3019 & 0.0596 & 0.1178 & 0.2357 & 0.1818 & 0.2360 & 0.2764 & 0.1164 & 0.1758 & 0.2774 & 0.1856 \\
0.1838 & 0.0858 & 0.2392 & 0.2440 & 0.1747 & 0.1216 & 0.2516 & 0.2286 & 0.2292 & 0.2775 & 0.2359 & 0.0997 & 0.2923 & 0.2565 & 0.3006 & 0.0595 & 0.1318 & 0.2029 & 0.1792 & 0.2483 & 0.2739 & 0.1584 & 0.2047 & 0.2896 & 0.1418 \\
0.1850 & 0.1040 & 0.2221 & 0.2222 & 0.2038 & 0.1163 & 0.3063 & 0.2579 & 0.2781 & 0.3390 & 0.2541 & 0.0938 & 0.3163 & 0.3260 & 0.3470 & 0.0652 & 0.1318 & 0.2224 & 0.2299 & 0.3039 & 0.3055 & 0.1276 & 0.2197 & 0.3351 & 0.1842 \\
0.1752 & 0.1115 & 0.2614 & 0.1835 & 0.2087 & 0.1231 & 0.2488 & 0.2196 & 0.2375 & 0.3187 & 0.2416 & 0.0891 & 0.2718 & 0.2959 & 0.3277 & 0.0618 & 0.1370 & 0.2240 & 0.2294 & 0.2730 & 0.2874 & 0.1337 & 0.2105 & 0.3165 & 0.1599 \\
0.1588 & 0.0809 & 0.2203 & 0.1589 & 0.1247 & 0.0905 & 0.2345 & 0.1980 & 0.2128 & 0.2243 & 0.1760 & 0.0732 & 0.2273 & 0.2485 & 0.2591 & 0.0513 & 0.1161 & 0.1489 & 0.1533 & 0.2420 & 0.2231 & 0.0976 & 0.1640 & 0.2645 & 0.1207 \\
0.2246 & 0.1383 & 0.2881 & 0.2476 & 0.2292 & 0.1130 & 0.3061 & 0.2423 & 0.2788 & 0.3520 & 0.2651 & 0.1125 & 0.3178 & 0.3261 & 0.3621 & 0.0684 & 0.1671 & 0.2485 & 0.2102 & 0.3171 & 0.3322 & 0.1347 & 0.2161 & 0.3497 & 0.1794 \\
0.2008 & 0.1268 & 0.2634 & 0.2687 & 0.2040 & 0.1409 & 0.2566 & 0.2436 & 0.2814 & 0.3761 & 0.2555 & 0.1160 & 0.3351 & 0.3475 & 0.3843 & 0.0700 & 0.1854 & 0.2533 & 0.2742 & 0.3378 & 0.3415 & 0.1535 & 0.2052 & 0.3718 & 0.1971 \\
0.1411 & 0.0870 & 0.2474 & 0.1856 & 0.1608 & 0.1105 & 0.2493 & 0.1584 & 0.1989 & 0.2739 & 0.2317 & 0.0791 & 0.2580 & 0.2673 & 0.2948 & 0.0553 & 0.1107 & 0.1729 & 0.1674 & 0.2598 & 0.2715 & 0.1057 & 0.1767 & 0.2847 & 0.1299 \\
0.2136 & 0.1171 & 0.2709 & 0.2336 & 0.2018 & 0.1285 & 0.2881 & 0.2273 & 0.2110 & 0.3476 & 0.2365 & 0.0931 & 0.3126 & 0.2801 & 0.3551 & 0.0645 & 0.1294 & 0.2496 & 0.2262 & 0.2977 & 0.3153 & 0.1262 & 0.1900 & 0.3296 & 0.1827 \\
0.1112 & 0.0612 & 0.1279 & 0.1445 & 0.1135 & 0.0671 & 0.1505 & 0.1122 & 0.1377 & 0.1538 & 0.1171 & 0.0555 & 0.1573 & 0.1496 & 0.2102 & 0.0396 & 0.0751 & 0.1226 & 0.1263 & 0.1572 & 0.2098 & 0.0727 & 0.1141 & 0.1892 & 0.0883 \\
0.1466 & 0.0898 & 0.2399 & 0.1781 & 0.1789 & 0.1001 & 0.2563 & 0.2293 & 0.2328 & 0.2964 & 0.1705 & 0.0815 & 0.2655 & 0.2598 & 0.3166 & 0.0568 & 0.1134 & 0.1650 & 0.1863 & 0.2662 & 0.2804 & 0.1089 & 0.1811 & 0.2927 & 0.1470 \\
0.1679 & 0.1225 & 0.2171 & 0.2278 & 0.1694 & 0.1483 & 0.2308 & 0.1901 & 0.2090 & 0.2701 & 0.1857 & 0.0746 & 0.2837 & 0.2648 & 0.2913 & 0.0579 & 0.1455 & 0.1858 & 0.2038 & 0.2696 & 0.2529 & 0.1443 & 0.1704 & 0.2826 & 0.1804 \\
0.1930 & 0.1059 & 0.2329 & 0.2248 & 0.1699 & 0.1166 & 0.2328 & 0.2067 & 0.2241 & 0.3002 & 0.2286 & 0.0832 & 0.2170 & 0.2633 & 0.2795 & 0.0579 & 0.1281 & 0.1852 & 0.2167 & 0.2543 & 0.2696 & 0.1260 & 0.1852 & 0.2827 & 0.1654 \\
0.1428 & 0.0877 & 0.2309 & 0.2003 & 0.1595 & 0.1116 & 0.2470 & 0.1791 & 0.1842 & 0.2857 & 0.1867 & 0.0807 & 0.2268 & 0.2146 & 0.2934 & 0.0551 & 0.1391 & 0.1888 & 0.1953 & 0.2721 & 0.2556 & 0.1362 & 0.1467 & 0.2839 & 0.1573 \\
0.1522 & 0.0984 & 0.1966 & 0.1806 & 0.1543 & 0.1083 & 0.2245 & 0.1734 & 0.2043 & 0.2904 & 0.1805 & 0.0904 & 0.2341 & 0.2416 & 0.2303 & 0.0534 & 0.1196 & 0.1830 & 0.1874 & 0.2347 & 0.2754 & 0.1169 & 0.1551 & 0.2595 & 0.1391 \\
0.1054 & 0.0661 & 0.1388 & 0.1420 & 0.1223 & 0.0730 & 0.1795 & 0.1351 & 0.1490 & 0.2243 & 0.1269 & 0.0608 & 0.1572 & 0.1787 & 0.2287 & 0.0330 & 0.0828 & 0.1185 & 0.1375 & 0.2014 & 0.2272 & 0.0799 & 0.1229 & 0.1922 & 0.1096 \\
0.1854 & 0.1097 & 0.2380 & 0.2170 & 0.1885 & 0.1351 & 0.2536 & 0.1967 & 0.2307 & 0.2936 & 0.2187 & 0.1001 & 0.2632 & 0.2724 & 0.3020 & 0.0596 & 0.1096 & 0.2052 & 0.2091 & 0.2777 & 0.2763 & 0.1309 & 0.1749 & 0.3058 & 0.1704 \\
0.1305 & 0.0640 & 0.1636 & 0.1225 & 0.1040 & 0.0709 & 0.1604 & 0.1189 & 0.1453 & 0.1860 & 0.1368 & 0.0584 & 0.1654 & 0.1860 & 0.2050 & 0.0412 & 0.0790 & 0.1051 & 0.1321 & 0.1802 & 0.1744 & 0.0917 & 0.1042 & 0.1975 & 0.1081 \\
0.1642 & 0.0924 & 0.2313 & 0.2110 & 0.1694 & 0.1031 & 0.2464 & 0.2052 & 0.2230 & 0.3168 & 0.2273 & 0.0969 & 0.2559 & 0.2792 & 0.3101 & 0.0583 & 0.1298 & 0.1983 & 0.1664 & 0.2573 & 0.2999 & 0.1127 & 0.1847 & 0.2991 & 0.1518 \\
0.1565 & 0.0884 & 0.2036 & 0.2019 & 0.1603 & 0.0989 & 0.2464 & 0.1661 & 0.2111 & 0.2875 & 0.1868 & 0.0937 & 0.2415 & 0.2791 & 0.3074 & 0.0553 & 0.1399 & 0.1754 & 0.1965 & 0.2059 & 0.2710 & 0.1215 & 0.1602 & 0.2972 & 0.1313 \\
0.1294 & 0.0719 & 0.1680 & 0.1546 & 0.1328 & 0.0798 & 0.1803 & 0.1483 & 0.1624 & 0.2541 & 0.1541 & 0.0653 & 0.2003 & 0.2220 & 0.2454 & 0.0461 & 0.0901 & 0.1303 & 0.1493 & 0.2019 & 0.1754 & 0.0877 & 0.1335 & 0.2370 & 0.1193 \\
0.1562 & 0.0941 & 0.1859 & 0.1690 & 0.1450 & 0.1184 & 0.1986 & 0.1923 & 0.1784 & 0.2292 & 0.1699 & 0.1001 & 0.2205 & 0.2415 & 0.2651 & 0.0500 & 0.1000 & 0.1448 & 0.1469 & 0.2353 & 0.2021 & 0.0870 & 0.1318 & 0.2420 & 0.1309 \\
0.1335 & 0.0826 & 0.2230 & 0.1907 & 0.1672 & 0.0917 & 0.2366 & 0.1883 & 0.1885 & 0.2741 & 0.2085 & 0.0748 & 0.2457 & 0.2397 & 0.2800 & 0.0526 & 0.1042 & 0.1502 & 0.1721 & 0.2185 & 0.2591 & 0.0996 & 0.1308 & 0.2707 & 0.1225 \\
0.1282 & 0.0716 & 0.1677 & 0.1671 & 0.1325 & 0.0800 & 0.1791 & 0.1486 & 0.1614 & 0.2245 & 0.1542 & 0.0657 & 0.1853 & 0.2215 & 0.2439 & 0.0458 & 0.1036 & 0.1298 & 0.1622 & 0.2015 & 0.2119 & 0.1006 & 0.1329 & 0.1828 & 0.1053 \\
0.2242 & 0.1238 & 0.2839 & 0.2617 & 0.1984 & 0.1370 & 0.3157 & 0.2120 & 0.2758 & 0.3657 & 0.2337 & 0.0999 & 0.3139 & 0.3391 & 0.3610 & 0.0680 & 0.1380 & 0.2484 & 0.2532 & 0.3009 & 0.3300 & 0.1919 & 0.1987 & 0.3609 & 0.1548
\end{bmatrix}
$$



CSF1	Good Communication and Collaboration between all stakeholders	**CSF2**	Fabricator Experience in Modules	**CSF3**	Robust drawing specifications and early design freeze	**CSF4**	Early Advice from Experts and Professionals	**CSF5**	Effective Use of IT Resources (e.g. BIM)	**CSF6**	Experience and Knowledge of Key players	**CSF7**	Precise project planning and control	**CSF8**	Standardization for mass production	**CSF9**	On-site and Off-site Coordination
CSF10	Supply Chain Coordination and Control	**CSF11**	Alignment of Modules and Project Requirements	**CSF12**	Manpower and Technicians' Experience	**CSF13**	Continuous Improvement	**CSF14**	Early Economic Analysis & Scope Definition	**CSF15**	Suitable Procurement and Contracting Strategies	**CSF16**	Availability of Local transportation infrastructure	**CSF17**	Availability of Key members at the earliest stages	**CSF18**	Effective coordination and management of stakeholders
CSF19	Early Involvement of Suppliers and Fabricators	**CSF20**	Appreciation of the Impact of Early Decisions	**CSF21**	Supply Chain Risk Management	**CSF22**	Availability of Skilled Technicians and supervisors	**CSF23**	Cosideration of Module Limitations	**CSF24**	Early completion and cost savings recognition	**CSF25**	Top Management Support and Involvement in Decision Making				

Figure 22 - Causal Diagram for CSFs

Table 16 - Impact Relationship Summary for CSFs

	CSF1	CSF2	CSF3	CSF4	CSF5	CSF6	CSF7	CSF8	CSF9	CSF10	CSF11	CSF12	CSF13	CSF14	CSF15	CSF16	CSF17	CSF18	CSF19	CSF20	CSF21	CSF22	CSF23	CSF24	CSF25	D
CSF1	0.1476	0.1094	**0.2681**	**0.2159**	0.1880	0.1201	**0.2828**	**0.2269**	**0.2603**	**0.2946**	**0.2208**	0.0849	**0.2801**	**0.2578**	**0.3019**	0.0596	0.1178	**0.2357**	0.1818	**0.2360**	**0.2764**	0.1164	0.1758	**0.2774**	0.1856	5.122
CSF2	0.1838	0.0858	**0.2392**	**0.2440**	0.1747	0.1216	**0.2516**	**0.2286**	**0.2292**	**0.2775**	**0.2359**	0.0997	**0.2923**	0.2565	**0.3006**	0.0595	0.1318	**0.2029**	0.1792	**0.2483**	**0.2739**	0.1584	**0.2047**	**0.2896**	0.1418	5.111
CSF3	0.1850	0.1040	**0.2221**	**0.2222**	**0.2038**	0.1163	**0.3063**	**0.2579**	**0.2781**	**0.3390**	**0.2541**	0.0938	**0.3163**	**0.3260**	**0.3470**	0.0652	0.1318	**0.2224**	**0.2299**	**0.3039**	**0.3055**	0.1276	**0.2197**	**0.3351**	0.1842	5.697
CSF4	0.1752	0.1115	**0.2614**	0.1835	**0.2087**	0.1231	**0.2488**	**0.2196**	**0.2375**	**0.3187**	**0.2416**	0.0891	**0.2718**	**0.2959**	**0.3277**	0.0618	0.1370	**0.2240**	**0.2294**	**0.2730**	**0.2874**	0.1337	**0.2105**	**0.3165**	0.1599	5.347
CSF5	0.1588	0.0809	**0.2203**	0.1589	0.1247	0.0905	**0.2345**	**0.1980**	**0.2128**	**0.2243**	0.1760	0.0732	**0.2273**	**0.2485**	**0.2591**	0.0513	0.1161	0.1489	0.1533	**0.2420**	**0.2231**	0.0976	0.1640	**0.2645**	0.1207	4.269
CSF6	**0.2246**	0.1383	**0.2881**	**0.2476**	**0.2292**	0.1130	**0.3061**	**0.2423**	**0.2788**	**0.3520**	**0.2651**	0.1125	**0.3178**	**0.3261**	**0.3621**	0.0684	0.1671	**0.2485**	**0.2102**	**0.3171**	**0.3322**	0.1347	**0.2161**	**0.3497**	0.1794	6.027
CSF7	**0.2008**	0.1268	**0.2634**	**0.2687**	**0.2040**	0.1409	**0.2566**	**0.2436**	**0.2814**	**0.3761**	**0.2555**	0.1160	**0.3351**	**0.3475**	**0.3843**	0.0700	0.1854	**0.2533**	**0.2742**	**0.3378**	**0.3415**	0.1535	**0.2052**	**0.3718**	**0.1971**	6.191
CSF8	0.1411	0.0870	**0.2474**	0.1856	0.1608	0.1105	**0.2493**	0.1584	**0.1989**	**0.2739**	**0.2317**	0.0791	**0.2580**	**0.2673**	**0.2948**	0.0553	0.1107	0.1729	0.1674	**0.2598**	**0.2715**	0.1057	0.1767	**0.2847**	0.1299	4.678
CSF9	**0.2136**	0.1171	**0.2709**	**0.2336**	**0.2018**	0.1285	**0.2881**	**0.2273**	**0.2110**	**0.3476**	**0.2365**	0.0931	**0.3126**	**0.2801**	**0.3551**	0.0645	0.1294	**0.2496**	**0.2262**	**0.2977**	**0.3153**	0.1262	**0.1900**	**0.3296**	0.1827	5.628
CSF10	0.1112	0.0612	0.1279	0.1445	0.1135	0.0671	0.1505	0.1122	0.1377	0.1538	0.1171	0.0555	0.1573	0.1496	**0.2102**	0.0396	0.0751	0.1226	0.1263	0.1572	**0.2098**	0.0727	0.1141	0.1892	0.0883	3.064
CSF11	0.1466	0.0898	**0.2399**	0.1781	0.1789	0.1001	0.2563	**0.2293**	**0.2328**	**0.2964**	0.1705	0.0815	**0.2655**	**0.2598**	**0.3166**	0.0568	0.1134	0.1650	0.1863	**0.2662**	**0.2804**	0.1089	0.1811	**0.2927**	0.1470	4.840
CSF12	0.1679	0.1225	**0.2171**	**0.2278**	0.1694	0.1483	**0.2308**	**0.1901**	**0.2090**	**0.2701**	0.1857	0.0746	**0.2837**	**0.2648**	**0.2913**	0.0579	0.1455	0.1858	**0.2038**	**0.2696**	**0.2529**	0.1443	0.1704	**0.2826**	0.1804	4.946
CSF13	**0.1930**	0.1059	**0.2329**	**0.2248**	0.1699	0.1166	**0.2328**	**0.2067**	**0.2241**	**0.3002**	**0.2286**	0.0832	**0.2170**	**0.2633**	**0.2795**	0.0579	0.1281	0.1852	**0.2167**	**0.2543**	**0.2696**	0.1260	0.1852	**0.2827**	0.1654	4.950
CSF14	0.1428	0.0877	**0.2309**	**0.2003**	0.1595	0.1116	**0.2470**	0.1791	0.1842	**0.2857**	0.1867	0.0807	**0.2268**	**0.2146**	**0.2934**	0.0551	0.1391	0.1888	**0.1953**	**0.2721**	0.2556	0.1362	0.1467	**0.2839**	0.1573	4.661
CSF15	0.1522	0.0984	**0.1966**	0.1806	0.1543	0.1083	**0.2245**	0.1734	**0.2043**	**0.2904**	0.1805	0.0904	**0.2341**	**0.2416**	**0.2303**	0.0534	0.1196	0.1830	0.1874	**0.2347**	**0.2754**	0.1169	0.1551	**0.2595**	0.1391	4.484
CSF16	0.1054	0.0661	0.1388	0.1420	0.1223	0.0730	0.1795	0.1351	0.1490	**0.2243**	0.1269	0.0608	0.1572	0.1787	**0.2287**	0.0330	0.0828	0.1185	0.1375	**0.2014**	**0.2272**	0.0799	0.1229	**0.1922**	0.1096	3.393
CSF17	0.1854	0.1097	**0.2380**	**0.2170**	0.1885	0.1351	**0.2536**	**0.1967**	**0.2307**	**0.2936**	**0.2187**	0.1001	**0.2632**	**0.2724**	**0.3020**	0.0596	0.1096	**0.2052**	**0.2091**	**0.2777**	**0.2763**	0.1309	0.1749	**0.3058**	0.1704	5.124
CSF18	0.1305	0.0640	0.1636	0.1225	0.1040	0.0709	0.1604	0.1189	0.1453	0.1860	0.1368	0.0584	0.1654	0.1860	**0.2050**	0.0412	0.0790	0.1051	0.1321	0.1802	0.1744	0.0917	0.1042	**0.1975**	0.1081	3.231
CSF19	0.1642	0.0924	**0.2313**	**0.2110**	0.1694	0.1031	**0.2464**	**0.2052**	**0.2230**	**0.3168**	**0.2273**	0.0969	0.2559	**0.2792**	**0.3101**	0.0583	0.1298	**0.1983**	0.1664	**0.2573**	**0.2999**	0.1127	0.1847	**0.2991**	0.1518	4.991
CSF20	0.1565	0.0884	**0.2036**	**0.2019**	0.1603	0.0989	**0.2464**	0.1661	**0.2111**	**0.2875**	0.1868	0.0937	**0.2415**	**0.2791**	**0.3074**	0.0553	0.1399	0.1754	**0.1965**	**0.2059**	**0.2710**	0.1215	0.1602	**0.2972**	0.1313	4.683
CSF21	0.1294	0.0719	0.1680	0.1546	0.1328	0.0798	0.1803	0.1483	0.1624	**0.2541**	0.1541	0.0653	**0.2003**	**0.2220**	**0.2454**	0.0461	0.0901	0.1303	0.1493	**0.2019**	0.1754	0.0877	0.1335	**0.2370**	0.1193	3.740
CSF22	0.1562	0.0941	0.1859	0.1690	0.1450	0.1184	**0.1986**	**0.1923**	0.1784	**0.2292**	0.1699	0.1001	**0.2205**	**0.2415**	**0.2651**	0.0500	0.1000	0.1448	0.1469	**0.2353**	**0.2021**	0.0870	0.1318	**0.2420**	0.1309	4.135
CSF23	0.1335	0.0826	**0.2230**	**0.1907**	0.1672	0.0917	**0.2366**	0.1883	0.1885	**0.2741**	**0.2085**	0.0748	**0.2457**	**0.2397**	**0.2800**	0.0526	0.1042	0.1502	0.1721	**0.2185**	**0.2591**	0.0996	0.1308	**0.2707**	0.1225	4.405
CSF24	0.1282	0.0716	0.1677	0.1671	0.1325	0.0800	0.1791	0.1486	0.1614	**0.2245**	0.1542	0.0657	0.1853	**0.2215**	**0.2439**	0.0458	0.1036	0.1298	0.1622	**0.2015**	**0.2119**	0.1006	0.1329	0.1828	0.1053	3.707
CSF25	**0.2242**	0.1238	**0.2839**	**0.2617**	**0.1984**	0.1370	**0.3157**	**0.2120**	**0.2758**	**0.3657**	**0.2337**	0.0999	**0.3139**	**0.3391**	**0.3610**	0.0680	0.1380	**0.2484**	**0.2532**	**0.3009**	**0.3300**	**0.1919**	**0.1987**	**0.3609**	0.1548	5.991
R	4.0578	2.3908	5.5299	4.9536	4.1614	2.7045	5.9626	4.8048	5.3057	7.0560	5.0031	2.1229	6.2446	6.4586	7.3026	1.3861	3.0248	4.5944	4.6925	6.2505	6.5980	2.9621	4.1899	6.9948	3.6630	

4.4.2 Fuzzy DEMATEL Results Summary for CSFs

From Table 15, it can be seen that out of the 25 CSFs, 15 CSFs (CSF1, CSF2, CSF3, CSF4, CSF5, CSF6, CSF7, CSF9, CSF12, CSF16, CSF17, CSF19, CSF22, CSF23, CSF25) were found to be causes and 10 CSFs (CSF8, CSF10, CSF11, CSF13, CSF14, CSF15, CSF18, CSF20, CSF21, CSF24) were found to be effect.

The causal diagram (figure 22) and the impact relationship table (table 16) show that there are 5 Cause CSFs (CSF2, CSF6, CSF12, CSF16 & CSF17) that are not influenced by any other factors.

4.4.3 Fuzzy DEMATEL Results Discussion for CSFs

The results gathered from the Fuzzy DEMATEL Data Analysis summarized in Table 15, Table 16 and Figure 22 indicate that:

- **Influence Criteria:**
  - <u>Causes:</u>
    - CSF1 - Good Communication and Collaboration between all stakeholders
    - CSF2 - Fabricator Experience in Modules
    - CSF3 - Robust drawing specifications and early design freeze
    - CSF4 - Early Advice from Experts and Professionals
    - CSF5 - Effective Use of IT Resources (e.g. BIM)
    - CSF6 - Experience and Knowledge of Key players
    - CSF7 - Precise project planning and control
    - CSF9 - On-site and Off-site Coordination
    - CSF12 - Manpower and Technicians' Experience
    - CSF16 - Availability of Local transportation infrastructure

        - CSF17 - Availability of Key members at the earliest stages
        - CSF19 - Early Involvement of Suppliers and Fabricators
        - CSF22 - Availability of Skilled Technicians and supervisors
        - CSF23 - Consideration of Module Limitations
        - CSF25 - Top Management Support and Involvement in Decision Making
    - <u>Effects:</u>
        - CSF8 - Standardization for mass production
        - CSF10 - Supply Chain Coordination and Control
        - CSF11 - Alignment of Modules and Project Requirements
        - CSF13 - Continuous Improvement
        - CSF14 - Early Economic Analysis & Scope Definition
        - CSF15 - Suitable Procurement and Contracting Strategies
        - CSF18 - Effective coordination and management of stakeholders
        - CSF20 - Appreciation of the Impact of Early Decisions
        - CSF21 - Supply Chain Risk Management
        - CSF24 - Early completion and cost savings recognition
- **Influence wise:**
    - <u>Most Influential Factor (Highest D Value):</u>
        - CSF7 - Precise project planning and control
    - <u>Least Influential Factor (Lowest D Value)</u>
        - CSF10 - Supply Chain Coordination and Control
- **Relationship wise:**
    - <u>Most influenced/ Affected factor (lowest relationship factor (D-R)):</u>
        - CSF10 - Supply Chain Coordination and Control

- Least influenced/ Affected factor (Highest relationship factor (D-R)):
  - CSF6 - Experience and Knowledge of Key players

The results indicate that CSF7 (Precise project planning and control) is the most influential Factor and that CSF10 (Supply Chain Coordination and Control) is both the least influential factor and most influenced factor while CSF6 (Experience and Knowledge of Key players) is the least influenced factor as it is not affected by any of the other CSFs. Tables 17 and 18 summarize the raking of the CSFs based on their influence and relationships respectively.

Table 17 - CSF Influence Rank

Rank	Factor No.	CSF Description	D
1	CSF7	Precise project planning and control	6.1908
2	CSF6	Experience and Knowledge of Key players	6.0269
3	CSF25	Top Management Support and Involvement in Decision Making	5.9906
4	CSF3	Robust drawing specifications and early design freeze	5.6971
5	CSF9	On-site and Off-site Coordination	5.6281
6	CSF4	Early Advice from Experts and Professionals	5.3472
7	CSF17	Availability of Key members at the earliest stages	5.1242
8	CSF1	Good Communication and Collaboration between all stakeholders	5.1217
9	CSF2	Fabricator Experience in Modules	5.1110
10	CSF19	Early Involvement of Suppliers and Fabricators	4.9905
11	CSF13	Continuous Improvement	4.9496
12	CSF12	Manpower and Technicians' Experience	4.9462
13	CSF11	Alignment of Modules and Project Requirements	4.8398
14	CSF20	Appreciation of the Impact of Early Decisions	4.6833
15	CSF8	Standardization for mass production	4.6783
16	CSF14	Early Economic Analysis & Scope Definition	4.6613
17	CSF15	Suitable Procurement and Contracting Strategies	4.4838
18	CSF23	Consideration of Module Limitations	4.4053
19	CSF5	Effective Use of IT Resources (e.g. BIM)	4.2693
20	CSF22	Availability of Skilled Technicians and supervisors	4.1351

Rank	Factor No.	CSF Description	D
21	CSF21	Supply Chain Risk Management	3.7396
22	CSF24	Early completion and cost savings recognition	3.7074
23	CSF16	Availability of Local transportation infrastructure	3.3930
24	CSF18	Effective coordination and management of stakeholders	3.2310
25	CSF10	Supply Chain Coordination and Control	3.0640

Table 18 - CSFs Relationship Rank

Rank	Factor No.	CSF Description	D-R
1	CSF10	Supply Chain Coordination and Control	-3.9921
2	CSF24	Early completion and cost savings recognition	-3.2874
3	CSF21	Supply Chain Risk Management	-2.8584
4	CSF15	Suitable Procurement and Contracting Strategies	-2.8188
5	CSF14	Early Economic Analysis & Scope Definition	-1.7973
6	CSF20	Appreciation of the Impact of Early Decisions	-1.5672
7	CSF18	Effective coordination and management of stakeholders	-1.3634
8	CSF13	Continuous Improvement	-1.2950
9	CSF11	Alignment of Modules and Project Requirements	-0.1633
10	CSF8	Standardization for mass production	-0.1265
11	CSF5	Effective Use of IT Resources (e.g. BIM)	0.1079
12	CSF3	Robust drawing specifications and early design freeze	0.1671
13	CSF23	Consideration of Module Limitations	0.2154
14	CSF7	Precise project planning and control	0.2283
15	CSF19	Early Involvement of Suppliers and Fabricators	0.2981
16	CSF9	On-site and Off-site Coordination	0.3224
17	CSF4	Early Advice from Experts and Professionals	0.3936
18	CSF1	Good Communication and Collaboration between all stakeholders	1.0639
19	CSF22	Availability of Skilled Technicians and supervisors	1.1730
20	CSF16	Availability of Local transportation infrastructure	2.0069
21	CSF17	Availability of Key members at the earliest stages	2.0994
22	CSF25	Top Management Support and Involvement in Decision Making	2.3276
23	CSF2	Fabricator Experience in Modules	2.7202
24	CSF12	Manpower and Technicians' Experience	2.8233
25	CSF6	Experience and Knowledge of Key players	3.3224

To compare the results of the CSF fuzzy DEMATEL with the results of section 4.3, the CSFs were grouped into the same PSFs found in section 4.2 (figure 19) as shown in table 19. Tables 20 and 21 show the PSF influence and relationship rank based on the CSF fuzzy DEMATEL Data Analysis.

Table 19 - Combined CSF and Relevant CSF DEMATEL Summary

Factor No.	CSF Description	D	R	D+R	D-R	Criteria
PSF1	**Project Coordination & Quality Management**	**19.9687**	**19.7695**	**39.7381**	**0.1992**	**CAUSE**
CSF1	Good Communication and Collaboration between all stakeholders	5.1217	4.0578	9.1794	1.0639	**CAUSE**
CSF5	Effective Use of IT Resources (e.g. BIM)	4.2693	4.1614	8.4308	0.1079	**CAUSE**
CSF9	On-site and Off-site Coordination	5.6281	5.3057	10.9338	0.3224	**CAUSE**
CSF13	Continuous Improvement	4.9496	6.2446	11.1942	-1.2950	**EFFECT**
PSF2	**Human Resources Management**	**20.2192**	**10.1803**	**30.3996**	**10.0389**	**CAUSE**
CSF2	Fabricator Experience in Modules	5.1110	2.3908	7.5018	2.7202	**CAUSE**
CSF6	Experience and Knowledge of Key players	6.0269	2.7045	8.7314	3.3224	**CAUSE**
CSF12	Manpower and Technicians' Experience	4.9462	2.1229	7.0692	2.8233	**CAUSE**
CSF22	Availability of Skilled Technicians and supervisors	4.1351	2.9621	7.0972	1.1730	**CAUSE**
PSF3	**Design & Specification Control & Management**	**19.6205**	**19.5278**	**39.1482**	**0.0927**	**CAUSE**
CSF3	Robust drawing specifications and early design freeze	5.6971	5.5299	11.2270	0.1671	**CAUSE**
CSF8	Standardization for mass production	4.6783	4.8048	9.4832	-0.1265	**EFFECT**
CSF11	Alignment of Modules and Project Requirements	4.8398	5.0031	9.8429	-0.1633	**EFFECT**
CSF23	Consideration of Module Limitations	4.4053	4.1899	8.5951	0.2154	**CAUSE**
PSF4	**Procurement Control**	**14.6804**	**22.3427**	**37.0231**	**-7.6624**	**EFFECT**
CSF10	Supply Chain Coordination and Control	3.0640	7.0560	10.1200	-3.9921	**EFFECT**
CSF15	Suitable Procurement and Contracting Strategies	4.4838	7.3026	11.7864	-2.8188	**EFFECT**
CSF16	Availability of Local transportation infrastructure	3.3930	1.3861	4.7790	2.0069	**CAUSE**
CSF21	Supply Chain Risk Management	3.7396	6.5980	10.3376	-2.8584	**EFFECT**
PSF5	**Early Commitment & Engagement**	**15.4620**	**12.6709**	**28.1329**	**2.7910**	**CAUSE**

Factor No.	CSF Description	D	R	D+R	D-R	Criteria
CSF4	Early Advice from Experts and Professionals	5.3472	4.9536	10.3009	0.3936	CAUSE
CSF17	Availability of Key members at the earliest stages	5.1242	3.0248	8.1490	2.0994	CAUSE
CSF19	Early Involvement of Suppliers and Fabricators	4.9905	4.6925	9.6830	0.2981	CAUSE
PSF6	**Schedule Planning & Stakeholder Management**	**15.4124**	**14.2199**	**29.6323**	**1.1925**	CAUSE
CSF7	Precise project planning and control	6.1908	5.9626	12.1534	0.2283	CAUSE
CSF18	Effective coordination and management of stakeholders	3.2310	4.5944	7.8253	-1.3634	EFFECT
CSF25	Top Management Support and Involvement in Decision Making	5.9906	3.6630	9.6536	2.3276	CAUSE
PSF7	**Cost Control & Management**	**13.0520**	**19.7039**	**32.7560**	**-6.6519**	EFFECT
CSF14	Early Economic Analysis & Scope Definition	4.6613	6.4586	11.1200	-1.7973	EFFECT
CSF20	Appreciation of the Impact of Early Decisions	4.6833	6.2505	10.9337	-1.5672	EFFECT
CSF24	Early completion and cost savings recognition	3.7074	6.9948	10.7023	-3.2874	EFFECT

Table 20 - New PSF Influence Rank

Rank	Factor No.	PSF Description	D
1	PSF2	Human Resources Management	20.2192
2	PSF1	Project Coordination & Quality Management	19.9687
3	PSF3	Design & Specification Control & Management	19.6205
4	PSF5	Early Commitment & Engagement	15.4620
5	PSF6	Schedule Planning & Stakeholder Management	15.4124
6	PSF4	Procurement Control	14.6804
7	PSF7	Cost Control & Management	13.0520

Table 21 - New PSF Relationship Rank

Rank	Factor No.	PSF Description	D-R
1	PSF4	Procurement Control	-7.6624
2	PSF7	Cost Control & Management	-6.6519
3	PSF3	Design & Specification Control & Management	0.0927
4	PSF1	Project Coordination & Quality Management	0.1992
5	PSF6	Schedule Planning & Stakeholder Management	1.1925
6	PSF5	Early Commitment & Engagement	2.7910
7	PSF2	Human Resources Management	10.0389

By comparing the results summarized in Tables 19, 20, and 21 and the results of section 4.3 summarized in Tables 13 and 14, it can be noticed that the cause/ effect criteria in both studies are the same but the rankings of the PSFs are different, while the least influential and least influenced factors, PSF7 (Cost Control & Management) and PSF 4 (Procurement Control) respectively, are the same in both studies the most influential and most influenced factors have changed.

When looking at the results from table 19, it is worth noting that not all the factors grouped under one PSF are from the same criteria for example while PSF4 (procurement control) is an effect but it includes CSF16 (Availability of Local transportation infrastructure) which is a cause, PSF1 and PSF3 have a similar issue, and this can explain why the rankings are different.

The grouping of the CSFs into the PSFs was done prior to the preparation of the DEMATEL survey and it was done based on the similarity and closeness of the factors and the causality was not considered at that stage.

It shall be noted that the CSF DEMATEL results are better for understanding the relationships between all the factors and these results are a more useful tool for helping project managers in taking action and decisions on actionable items under their control in projects unlike the PSF DEMATEL which would be more suitable for taking a strategic level decision from the high management and executives.

4.5 Overall Research Discussion

Since the main goal of this study was enabling project managers and professionals to make scientifically informed decisions, the results of the general survey found in section 4.2

and the results of the CSF DEMATEL found in section 4.4 were taken into consideration for this section.

The criticality found from the general survey, which gave the ranking and numbering for the CSFs, was considered for the ranking of the criticality of the 25 factors. The results found from the fuzzy DEMATEL method were used to classify the factors into causes and effects. Table 22 shows a summary of the causes (in blue) and effects (in red) and their ranking.

Table 22 - Causes and Effects Ranked

Factor No.	"Cause" CSF Description	Factor No.	"Effect" CSF Description
CSF1	Good Communication and Collaboration between all stakeholders	CSF8	Standardization for mass production
CSF2	Fabricator Experience in Modules	CSF10	Supply Chain Coordination and Control
CSF3	Robust drawing specifications and early design freeze	CSF11	Alignment of Modules and Project Requirements
CSF4	Early Advice from Experts and Professionals	CSF13	Continuous Improvement
CSF5	Effective Use of IT Resources (e.g. BIM)	CSF14	Early Economic Analysis & Scope Definition
CSF6	Experience and Knowledge of Key players	CSF15	Suitable Procurement and Contracting Strategies
CSF7	Precise project planning and control	CSF18	Effective coordination and management of stakeholders
CSF9	On-site and Off-site Coordination	CSF20	Appreciation of the Impact of Early Decisions
CSF12	Manpower and Technicians' Experience	CSF21	Supply Chain Risk Management
CSF16	Availability of Local transportation infrastructure	CSF24	Early completion and cost savings recognition
CSF17	Availability of Key members at the earliest stages		
CSF19	Early Involvement of Suppliers and Fabricators		
CSF22	Availability of Skilled Technicians and supervisors		
CSF23	Consideration of Module Limitations		
CSF25	Top Management Support and Involvement in Decision Making		

In general, the effects are usually controlled by the causes, and it would be wise for project managers and decision-makers to focus on the group of causes as they will influence the effects (Lin, 2012). However as shown previously in the influence and impact relationship summary (table 16), the relationship between causes and effects is complex as there are causes that are influenced by effects, Table 23 summarizes how many factors are impacting and are influenced by each other.

Table 23 - Impact and Influence Summary

Sr.	CSF Description	Impacting				Influenced By			
		Low	Medium	High	Overall	Low	Medium	High	Overall
CAUSES									
CSF1	Good Communication and Collaboration between all stakeholders	5	9	0	14	5	0	0	5
CSF2	Fabricator Experience in Modules	9	5	0	15	0	0	0	0
CSF3	Robust drawing specifications and early design freeze	7	6	4	17	13	6	0	19
CSF4	Early Advice from Experts and Professionals	8	7	1	16	12	2	0	14
CSF5	Effective Use of IT Resources (e.g. BIM)	9	2	0	11	6	0	0	6
CSF6	Experience and Knowledge of Key players	7	6	5	18	0	0	0	0
CSF7	Precise project planning and control	7	5	7	19	13	6	0	19
CSF9	On-site and Off-site Coordination	9	6	3	18	12	5	0	17
CSF12	Manpower and Technicians' Experience	7	6	0	13	0	0	0	0
CSF16	Availability of Local transportation infrastructure	5	0	0	5	0	0	0	0
CSF17	Availability of Key members at the earliest stages	8	7	0	15	0	0	0	0
CSF19	Early Involvement of Suppliers and Fabricators	7	6	0	14	10	1	0	11
CSF22	Availability of Skilled Technicians and supervisors	8	1	0	9	1	0	0	1
CSF23	Consideration of Module Limitations	7	4	0	11	7	0	0	7
CSF25	Top Management Support and Involvement in Decision Making	8	6	5	19	1	0	0	1

Sr.	CSF Description	Impacting				Influenced By			
		Low	Medium	High	Overall	Low	Medium	High	Overall
Effects									
CSF8	Standardization for mass production	4	7	0	11	14	1	0	15
CSF10	Supply Chain Coordination and Control	2	0	0	2	5	13	5	23
CSF11	Alignment of Modules and Project Requirements	3	7	0	11	12	1	0	13
CSF13	Continuous Improvement	10	5	0	15	8	11	1	20
CSF14	Early Economic Analysis & Scope Definition	6	4	0	11	7	10	4	21
CSF15	Suitable Procurement and Contracting Strategies	7	3	0	10	6	13	6	25
CSF18	Effective coordination and management of stakeholders	2	0	0	2	10	0	0	10
CSF20	Appreciation of the Impact of Early Decisions	7	5	0	12	11	11	1	23
CSF21	Supply Chain Risk Management	6	0	0	6	6	13	3	22
CSF24	Early completion and cost savings recognition	5	0	0	5	4	14	5	23

Once taking the previous results summarized in tables 22 and 23, the most effective way for the project managers' decision-making is to first look at the most critical effects and then find and improve the causes that are impacting them. For example, the Standardization for mass production (CSF8) is shown to be influenced by 15 different factors listed below (underlined factors are effect CSFs):

- CSF1 - Good Communication and Collaboration between all stakeholders
- CSF2 - Fabricator Experience in Modules
- CSF3 - Robust drawing specifications and early design freeze
- CSF4 - Early Advice from Experts and Professionals
- CSF5 - Effective Use of IT Resources (e.g. BIM)
- CSF6 - Experience and Knowledge of Key players

- CSF7 - Precise project planning and control
- CSF9 - On-site and Off-site Coordination
- CSF11 - Alignment of Modules and Project Requirements
- CSF12 - Manpower and Technicians' Experience
- CSF13 - Continuous Improvement
- CSF17 - Availability of Key members at the earliest stages
- CSF19 - Early Involvement of Suppliers and Fabricators
- CSF22 - Availability of Skilled Technicians and supervisors
- CSF25 - Top Management Support and Involvement in Decision Making

If project managers were to improve on the causes listed above, then the effect in question would be improved as well. It is worth noting here that project management is a really complex topic and there are many factors that go into the improvement of the causes and that part is not part of this research study.

Unfortunately, no literature was found on this same topic. However, the results found in this study were discussed with the experts consulted on this study and even though some of the experts had disagreements on a few points, the results were found to be in line with their opinions and experiences in general.

Chapter V: Conclusion

5.1 Research Conclusion

This research investigated the qualitative and quantitative influence and the relationship between different factors for the successful implementation of Offsite Modular Construction (OMC). This type of research can be beneficial for companies planning to study the feasibility of implementing offsite construction in future projects and for companies wanting to improve their standards and processes in offsite construction.

After gaining vital knowledge from a detailed literature review and a few rounds of consulting several subject matter experts, the critical success factors and eventually the principal success factors were found. This dissertation studied the use of a multi-criteria decision making (MCDM) process called Decision Making Trial and Evaluation Laboratory (DEMATEL) in association with Fuzzy set theory, to help remove vagueness and imprecision of the experts' biases, and the DEMATEL approach has found the causes, effects and relationship between OMC projects success factors for the PSFs and CSFs, the results are not alternatives but are rather complementary to each other as the PSF results aims to provide insight to the executives and top management, while the CSF results provide more insight on a lower scale and more detailed factors that are more helpful to the project managers' day to day decision making tasks.

The PSF analysis results of this study were that five principal success factors, Project Coordination & Quality Management (PSF1), Human Resources Management (PSF2), Design & Specification Control & Management (PSF3), Early Commitment & Engagement (PSF5) and Schedule Planning & Stakeholder Management (PSF6), were causes and that two PSFs, Procurement Control (PSF4) and Cost Control & Management (PSF7), were effects.

Additionally, it was found that Design & Specification Control & Management (PSF3) is the most influential factor, and Cost Control & Management (PSF7) is the least influential factor while Human Resources Management (PSF2) is the least affected by other factors and Cost Control & Management (PSF7) is very highly affected by other factors. These results are more helpful for the decision making of the top executive and management as it shows the most important factors at a high level and allows the top executives to focus on the departmental strategies on their respective companies as a whole and not on the individual project tasks and employees.

For the second part of the study, the CSF analysis results have shown that Precise project planning and control (CSF7) is the most influential factor and that Supply Chain Coordination and Control (CSF10) is both the least influential factor and the most influenced/ affected factor, while Experience and Knowledge of Key players (CSF6) is the least influenced factor. These results are more helpful for the project managers and employees for taking the best decisions when it comes to individual task which is in their direct control.

The overall results for this study can provide useful insight for the top executives and the project managers to assist them in their focus and decision making on the causes and effects under their control at their respective levels and authority.

5.2 Research Limitations

While this study was really important as not a lot of research is done on this subject in the middle east region, there were some limitations and obstacles faced in this research.

Firstly, several research papers were used for the literature review to find potential factors, but none of these papers were discussing the same exact topic of this paper and that might have not captured all the factors that are applicable for the UAE projects.

Secondly, due to the difficulty in collecting data, the factors were grouped together into 7 PSFs to ease the survey answering, while the grouping was done through the affinity diagram method, it needs to be noted that the grouping is not a 100% accurate representation of the CSFs it contained and that might have caused the experts to put values that could have been different if the factors were grouped or named differently. As can be seen from the results of section 4.4.

Finally, the majority of the experts that were consulted for this research were working in the same organization, all be it at different departments, and their opinions on some of the factors are very similar as there are issues that they didn't think were critical, if more people from other organizations were consulted the results would have been a better representation or the critical factors in the UAE.

It is worth noting that the lack of research in this topic in the middle east is because the use of prefabrication and offsite methods for construction in this region while not quite new but is not very common and it is worth being researched thoroughly in the future.

5.3 Research Implication and Future Work Recommendation

This research intended to help project managers and top executives in the United Arab Emirates and GCC region for decision making and focusing on the most important factors that would affect the implementation of Offsite Construction methodologies in projects.

The results found with the DEMATEL analysis can help the construction professionals on understanding the relationship and influence between different factors, the results have shown that there are some factors that are very critical but are influenced by other factors.

Finding this relationship would help the professionals in focusing and putting more effort on the right factors.

While fuzzy DEMATEL is a powerful and comprehensive MCDM method that can be used by different companies or researchers to ease solving problems involving decision-making. It must be noted that there were some limitations faced in this thesis like the limited number of respondents, the inability to find respondents working in different companies, and finally that the research grouped factors together for the DEMATEL to simplify the questionnaires as it would have it extremely difficult to find participants willing to spend a lot of time on the survey.

Future research in this topic is required, to find the best results and help executives and project managers in their decision making for deciding on implementing and improving offsite construction methodologies, by firstly finding potential factors from actual project data preferably from multiple projects, then finding the critical and principal success factors through a survey with a bigger sample of participants, and then using the same fuzzy DEMATEL method, by collecting data for a bigger sample of experts, for both the principal and critical success factors' influences and relationships with each other. This would be very helpful for the UAE constructing industry executives and project manager for taking the decisions at the strategic, project and task levels.

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Appendices

A. CSF Questionnaire Additional Documents

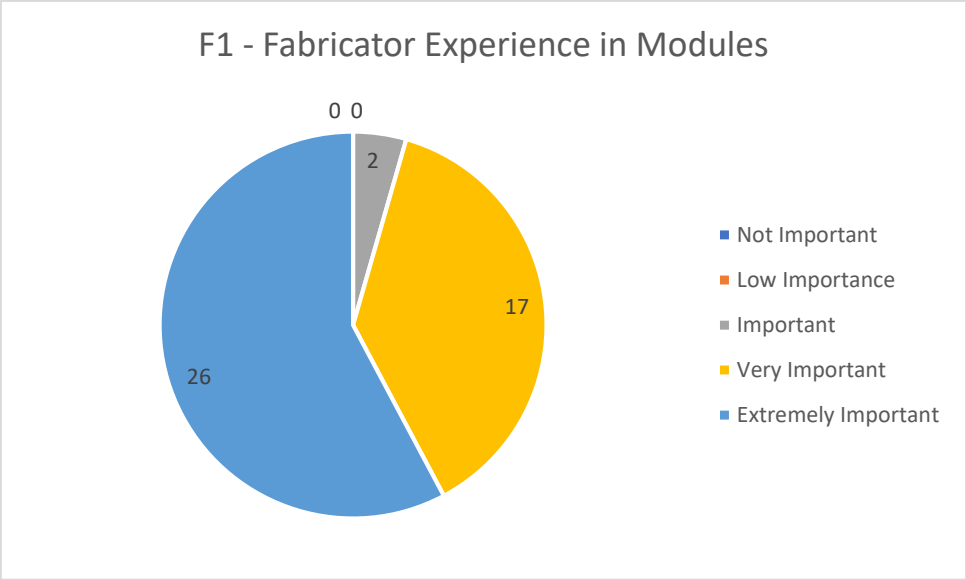
A.1. Sample CSF Questionnaire

Sr.	Question
Part 1	**Kindly fill the first section with your personal experience data.**
1	Which type of Institution do you currently work in?
2	What is your current Occupation?
3	How many years of experience in the construction industry do you have?
4	How many years of experience in modular/ prefabrication/ offsite construction do you have in the GCC region?
Part 2	**Kindly fill each question by selecting a value between 1 (not important at all) and 5 (extremely important)**
1	How critical/ important is the Fabricator experience and capabilities in modules design and production?
2	How critical/ important are Robust drawing specifications and early design freeze?
3	How critical/ important is the Good working collaboration, communication and information sharing among project participants?
4	How critical/ important is the Standardization and mass production?
5	How critical/ important is the Effective coordination of the supply chain segments?
6	How critical/ important is the Availability and active involvement of key project team members from the earliest stages of the project?
7	How critical/ important is the Extensive project planning, scheduling and control?
8	How critical/ important is the Experienced workforce and technical capability?
9	How critical/ important is the Early involvement of modules suppliers and fabricators?
10	How critical/ important is the Availability of skilled workforce, management and supervising team?
11	How critical/ important are Early advice and consideration from Modular Construction design experts and professionals?
12	How critical/ important is the Availability of sound local transport infrastructure and site equipment capabilities?
13	How critical/ important are Realistic economic analysis, early decision and definition of Modular Construction project scope?
14	How critical/ important is the Effective coordination and management of stakeholders?
15	How critical/ important is the Effective coordination of on-site and off-site trades?
16	How critical/ important is the Adequate experience and knowledge of key players?
17	How critical/ important is the Alignment on Modular Construction project drivers and modules architecture?

Sr.	Question
18	How critical/ important is Continuous improvement?
19	How critical/ important is Suitable procurement strategy and contracting?
20	How critical/ important is the Support and early involvement of top management in supply chain decision making?
21	How critical/ important is the Appreciation of key early decisions and their implication between all parties involved?
22	How critical/ important is the Effective use of information and communication technology (e.g. BIM)?
23	How critical/ important is the Effective supply chain and execution risk management?
24	How critical/ important are Early completion and cost savings recognition?
25	How critical/ important are Module envelope limitations?

A.2. Data Analysis for Factor from the CSF Questionnaire

Factor	Count of Rating				
	1	2	3	4	5
F1 - Fabricator Experience in Modules	*0*	*0*	*2*	*17*	*26*
F2 - Robust drawing specifications and early design freeze	*0*	*0*	*3*	*15*	*27*
F3 - Good Communication and Collaboration between all stakeholders	*0*	*0*	*1*	*8*	*36*
F4 - Standardization for mass production	*0*	*0*	*3*	*20*	*22*
F5 - Supply Chain Coordination and Control	*0*	*0*	*4*	*20*	*21*
F6 - Availability of Key members at the earliest stages	*0*	*0*	*6*	*20*	*19*
F7 - Precise project planning and control	*0*	*0*	*4*	*17*	*24*
F8 - Manpower and Technicians' Experience	*0*	*0*	*5*	*20*	*20*
F9 - Early Involvement of Suppliers and Fabricators	*0*	*1*	*5*	*22*	*17*
F10 - Availability of Skilled Technicians and supervisors	*0*	*2*	*7*	*18*	*18*
F11 - Early Advice from Experts and Professionals	*0*	*0*	*2*	*18*	*25*
F12 - Availability of Local transportation infrastructure	*0*	*0*	*5*	*21*	*19*
F13 - Early Economic Analysis & Scope Definition	*0*	*0*	*7*	*16*	*22*
F14 - Effective coordination and management of stakeholders	*0*	*1*	*3*	*26*	*15*
F15 - On-site and Off-site Coordination	*0*	*0*	*5*	*17*	*23*
F16 - Experience and Knowledge of Key players	*0*	*0*	*2*	*21*	*22*
F17 - Alignment of Modules and Project Requirements	*0*	*0*	*5*	*19*	*21*
F18 - Continuous Improvement	*0*	*1*	*6*	*15*	*23*
F19 - Suitable Procurement and Contracting Strategies	*0*	*0*	*2*	*27*	*16*
F20 - Top Management Support and Involvement in Decision Making	*0*	*3*	*7*	*20*	*15*
F21 - Appreciation of the Impact of Early Decisions	*0*	*1*	*4*	*25*	*15*
F22 - Effective Use of IT Resources (e.g. BIM)	*0*	*0*	*3*	*17*	*25*
F23 - Supply Chain Risk Management	*0*	*0*	*8*	*22*	*15*
F24 - Early completion and cost savings recognition	*0*	*1*	*10*	*17*	*17*
F25 - Consideration of Module Limitations	*0*	*1*	*7*	*22*	*15*


F1 - Fabricator Experience in Modules
0 0
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26
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Important
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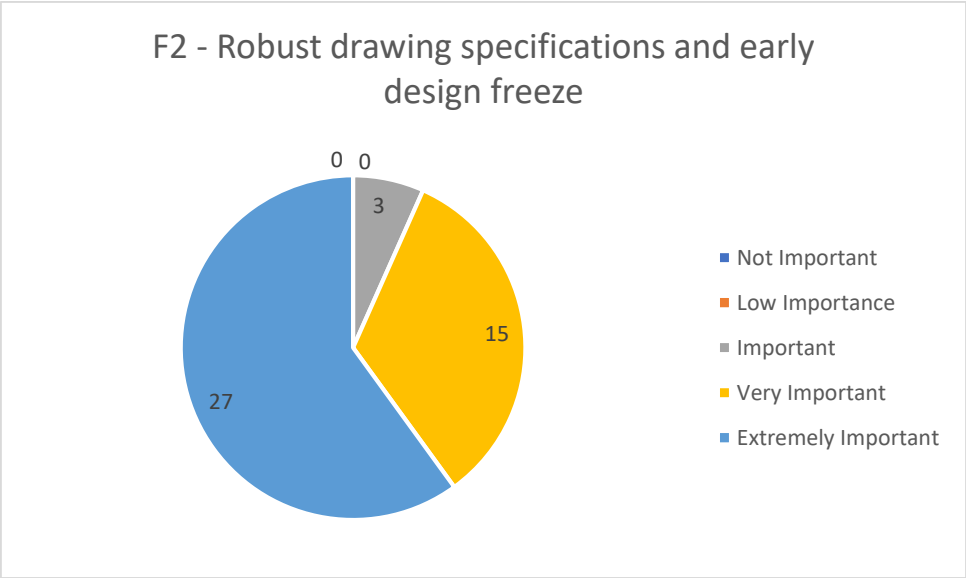
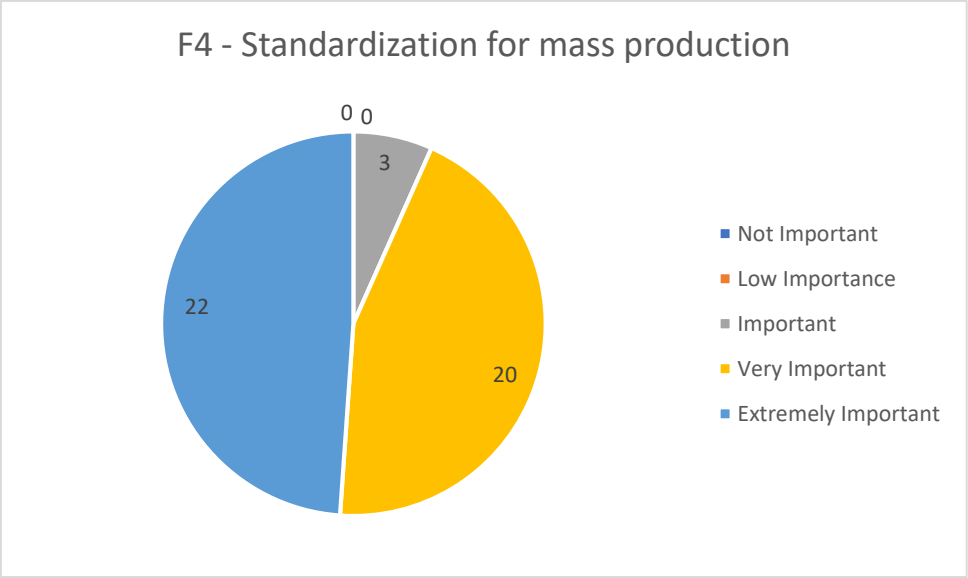
Extremely Important


F2 - Robust drawing specifications and early design freeze
0 0
3
15
27
Not Important
Low Importance
Important
Very Important
Extremely Important

F3 - Good Communication and Collaboration between all stakeholders
0 0
1
8
36
Not Important
Low Importance
Important
Very Important
Extremely Important


F4 - Standardization for mass production
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0
3
20
22
Not Important
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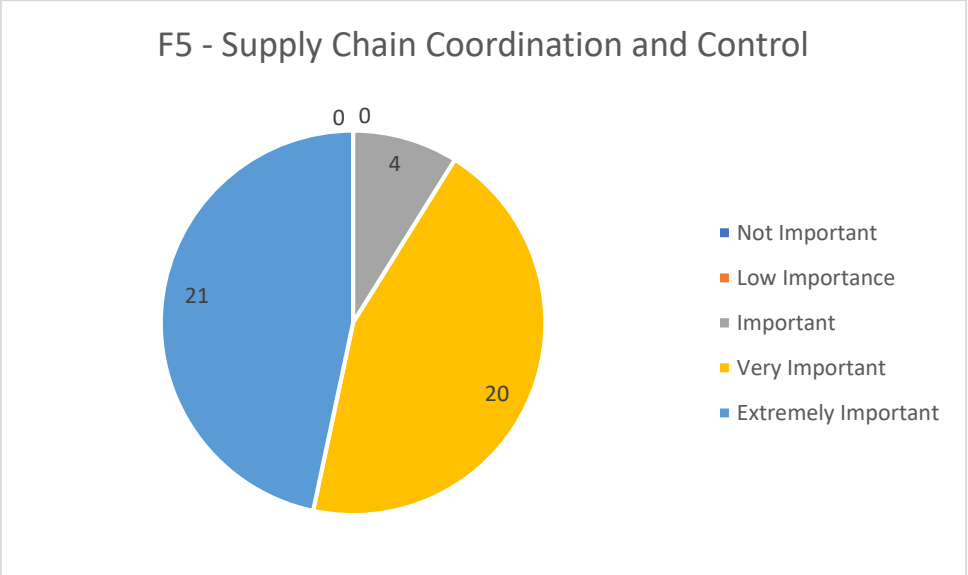
Important
Very Important
Extremely Important


F5 - Supply Chain Coordination and Control
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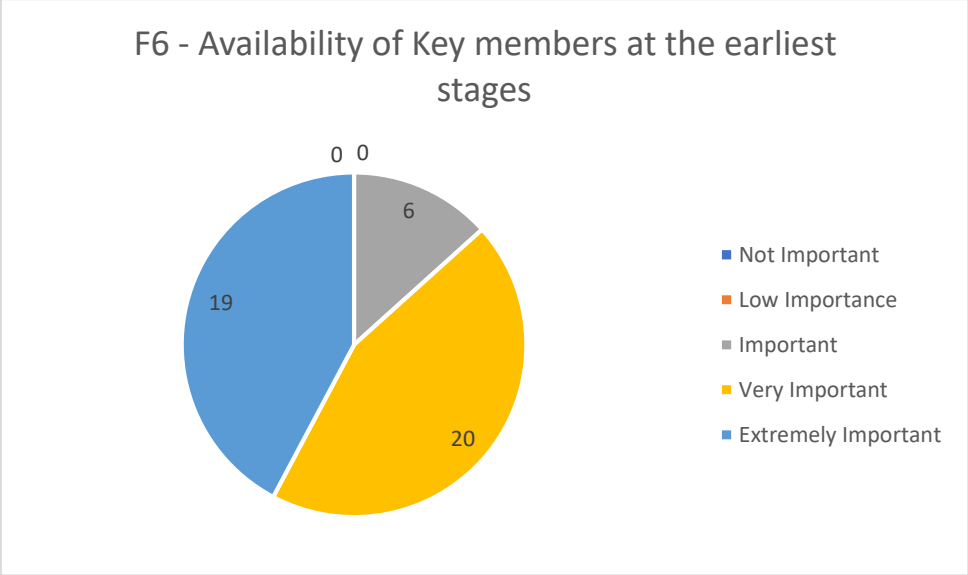
0
4
20
21
Not Important
Low Importance
Important
Very Important
Extremely Important


F6 - Availability of Key members at the earliest stages
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Not Important
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Very Important
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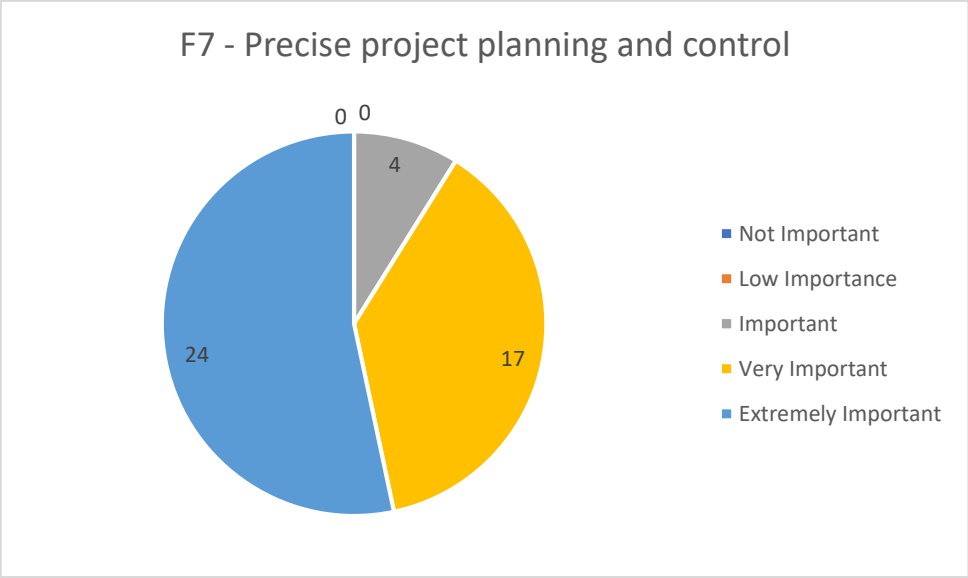
F7 - Precise project planning and control
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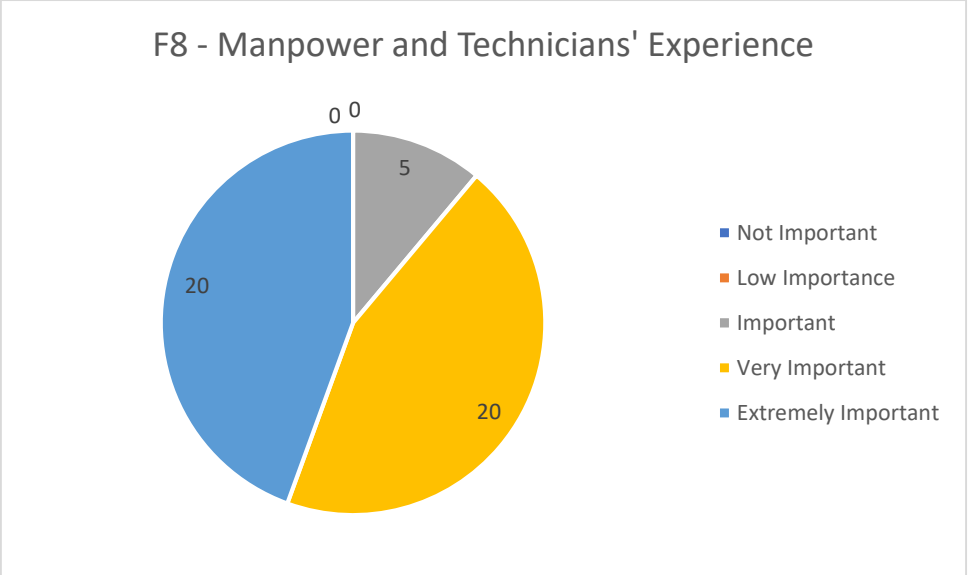
F8 - Manpower and Technicians' Experience
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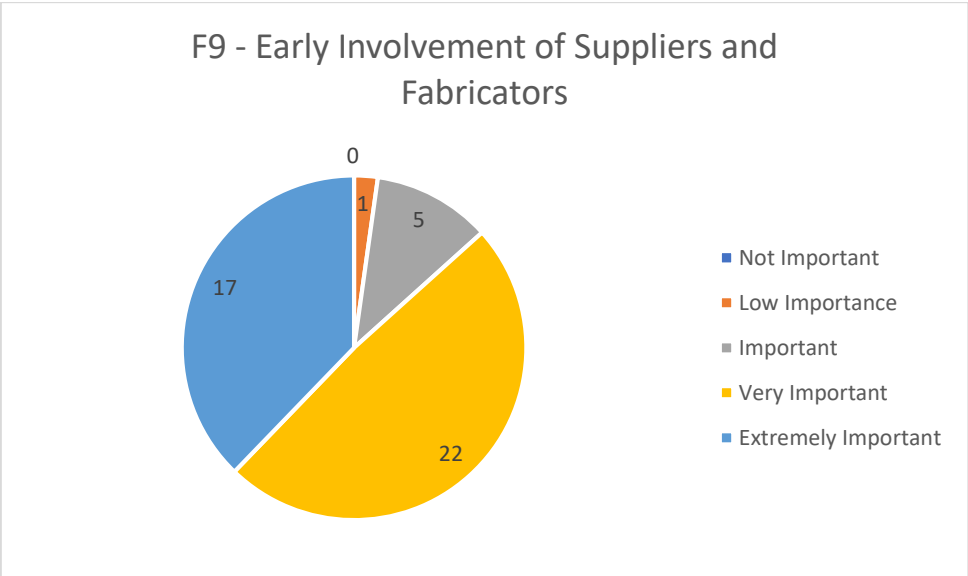
F9 - Early Involvement of Suppliers and Fabricators
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Not Important
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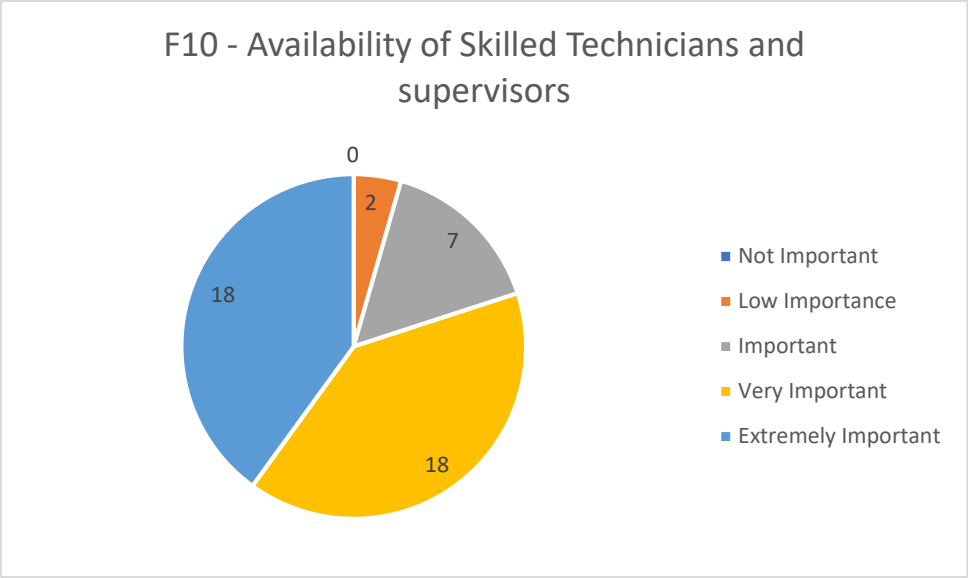
F10 - Availability of Skilled Technicians and supervisors
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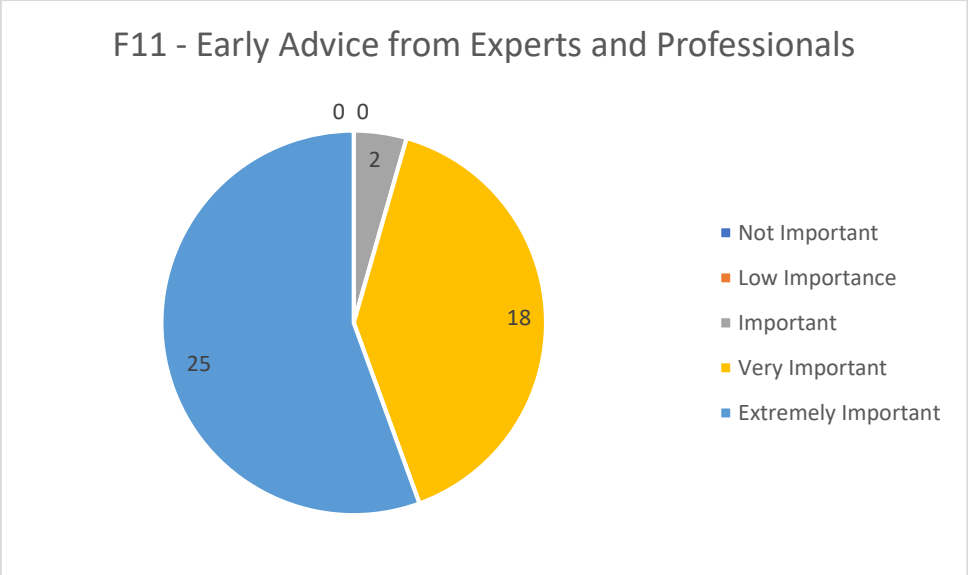
F11 - Early Advice from Experts and Professionals
0 0
2
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25
Not Important
Low Importance
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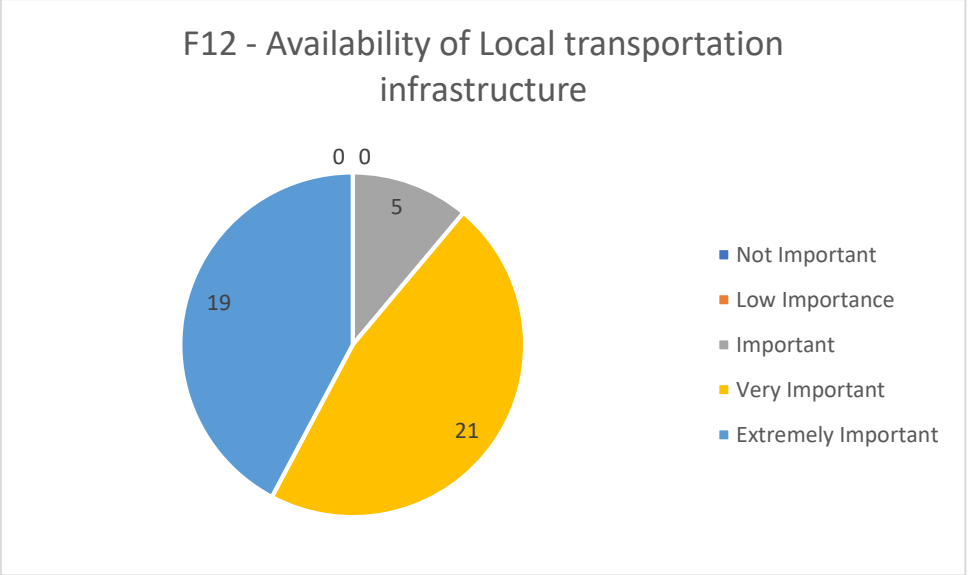
Extremely Important


F12 - Availability of Local transportation infrastructure
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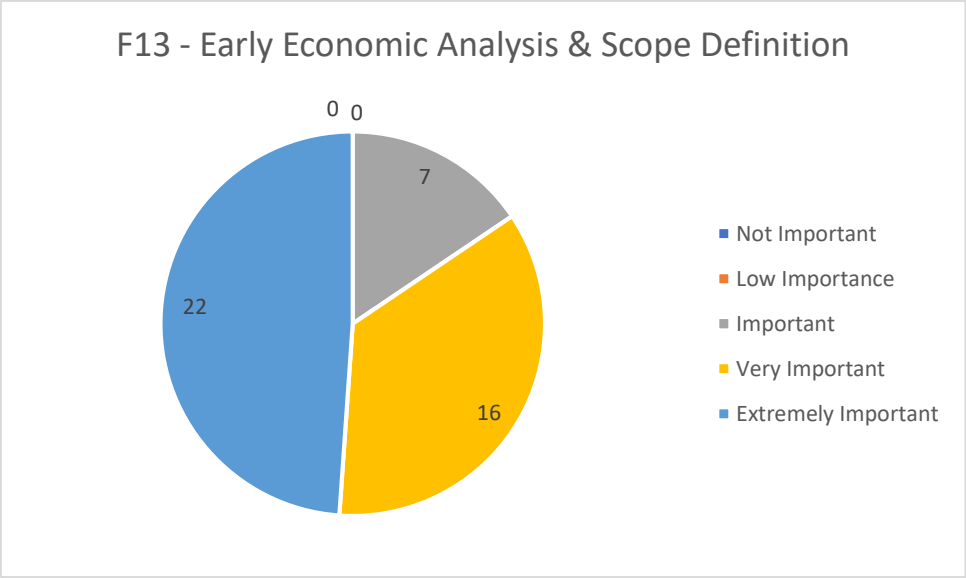
Extremely Important


F13 - Early Economic Analysis & Scope Definition
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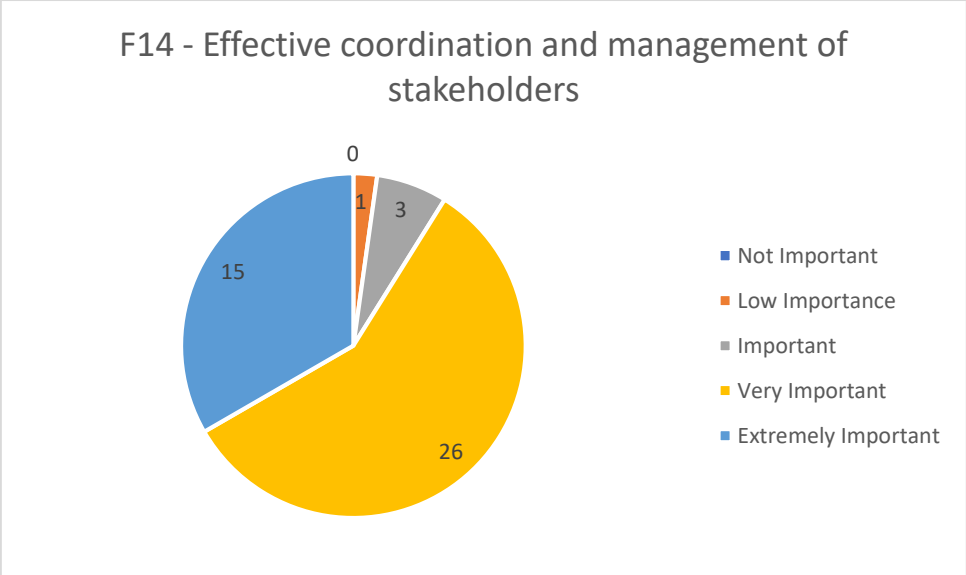
F14 - Effective coordination and management of stakeholders
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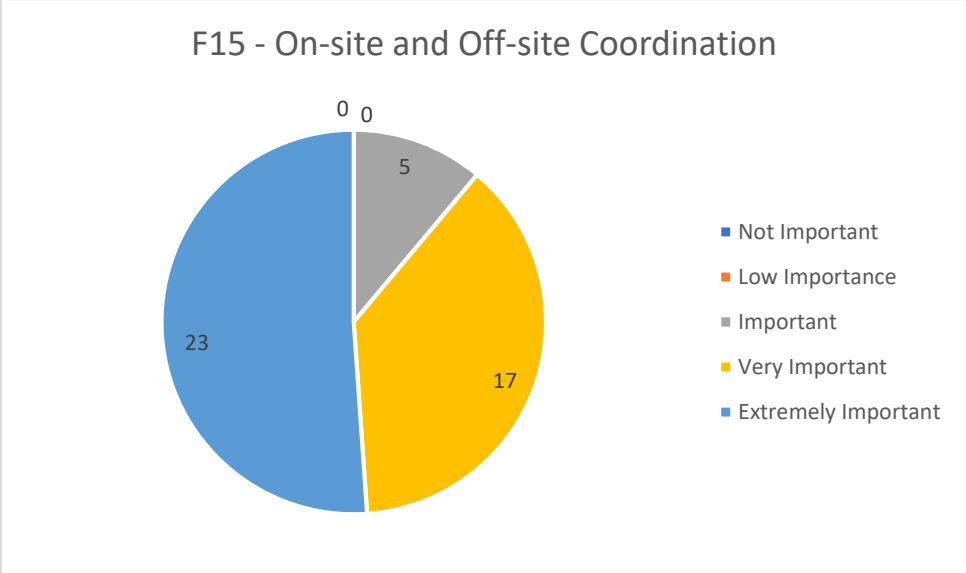
F15 - On-site and Off-site Coordination
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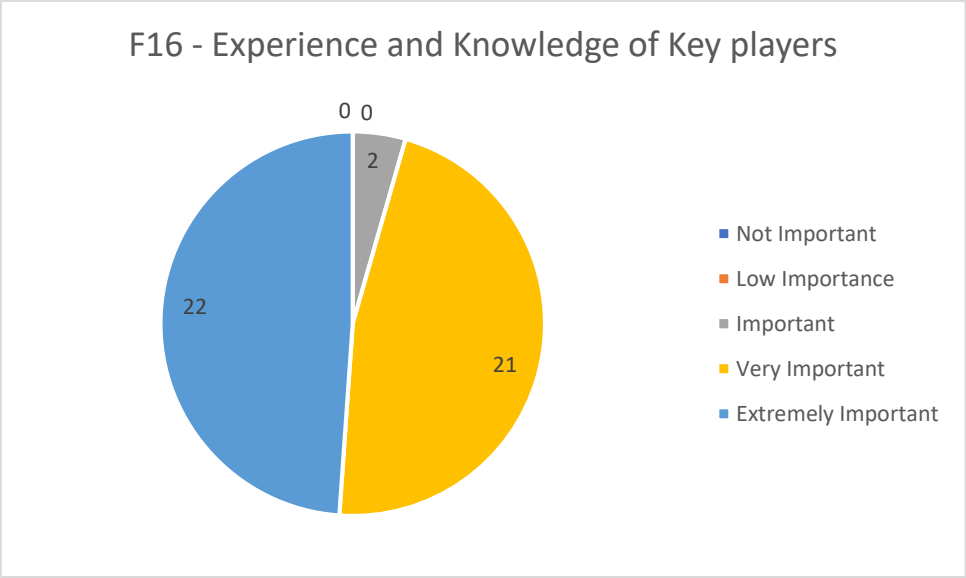
F16 - Experience and Knowledge of Key players
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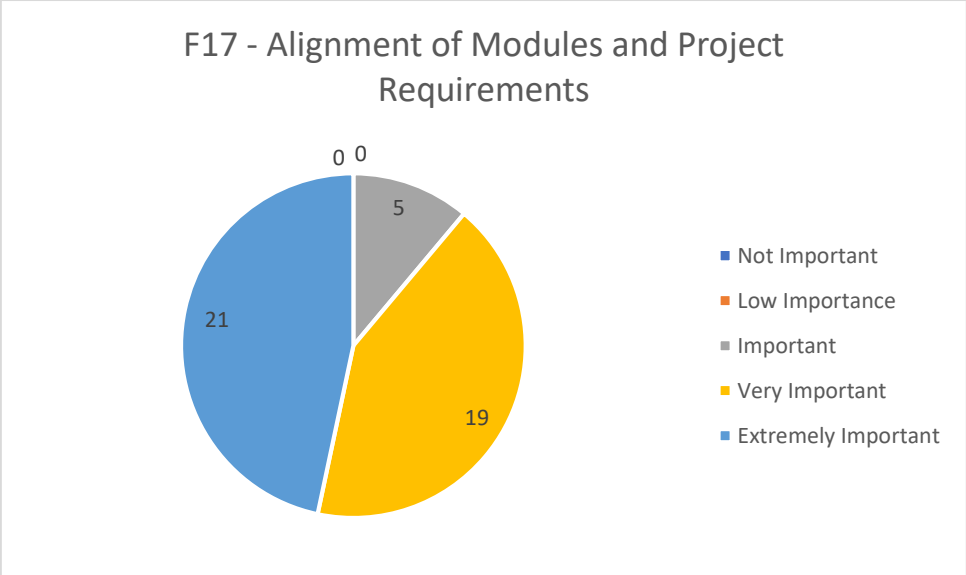
F17 - Alignment of Modules and Project Requirements
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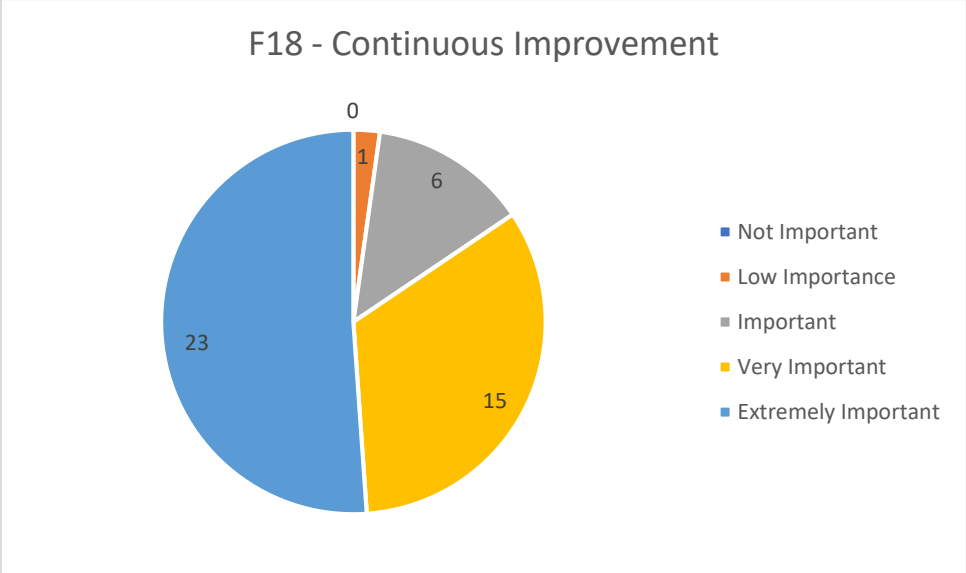
F18 - Continuous Improvement
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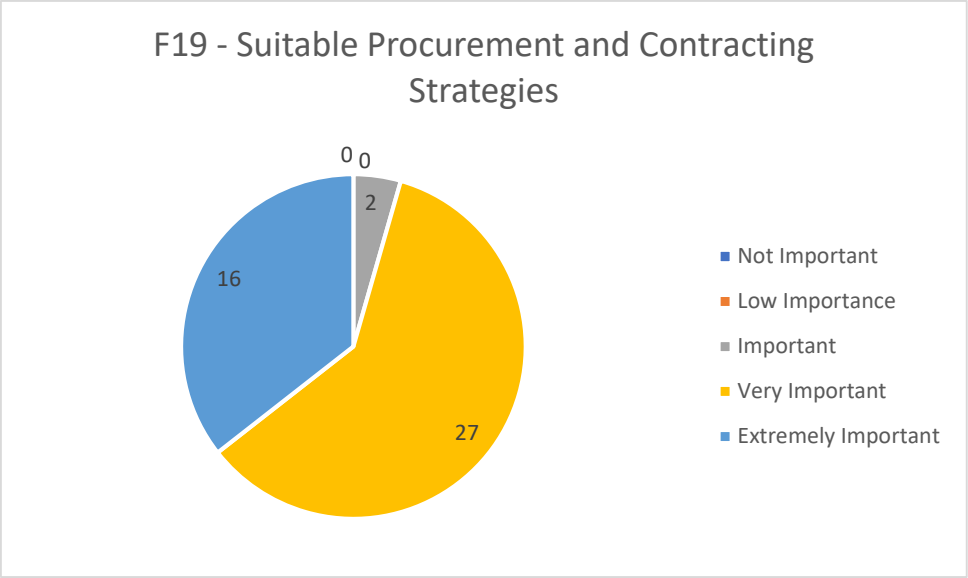
Extremely Important


F19 - Suitable Procurement and Contracting Strategies
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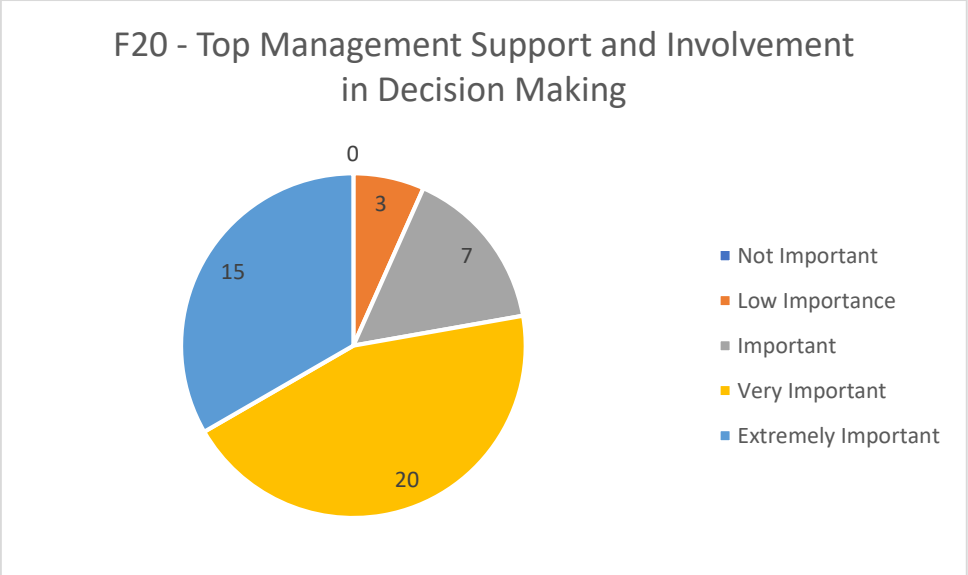
F20 - Top Management Support and Involvement in Decision Making
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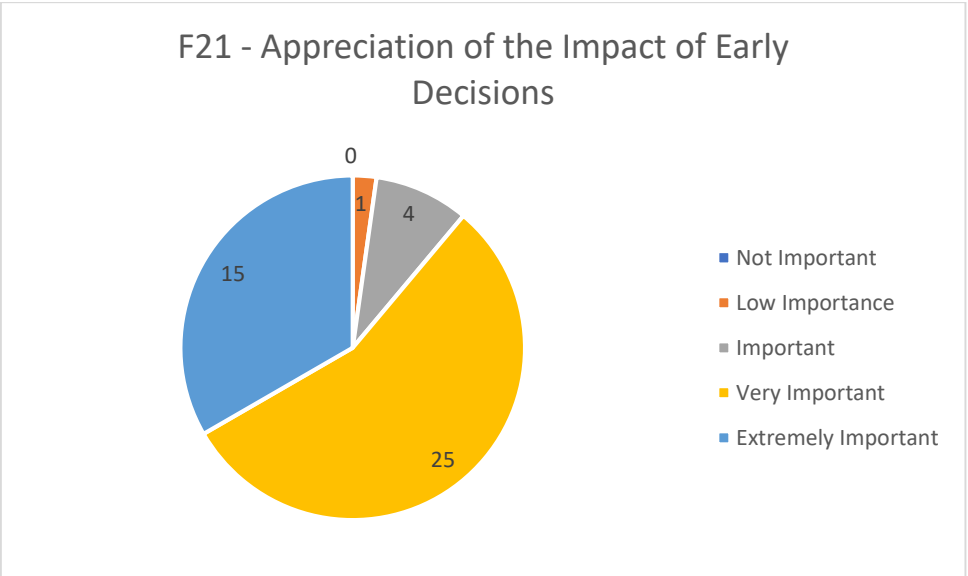
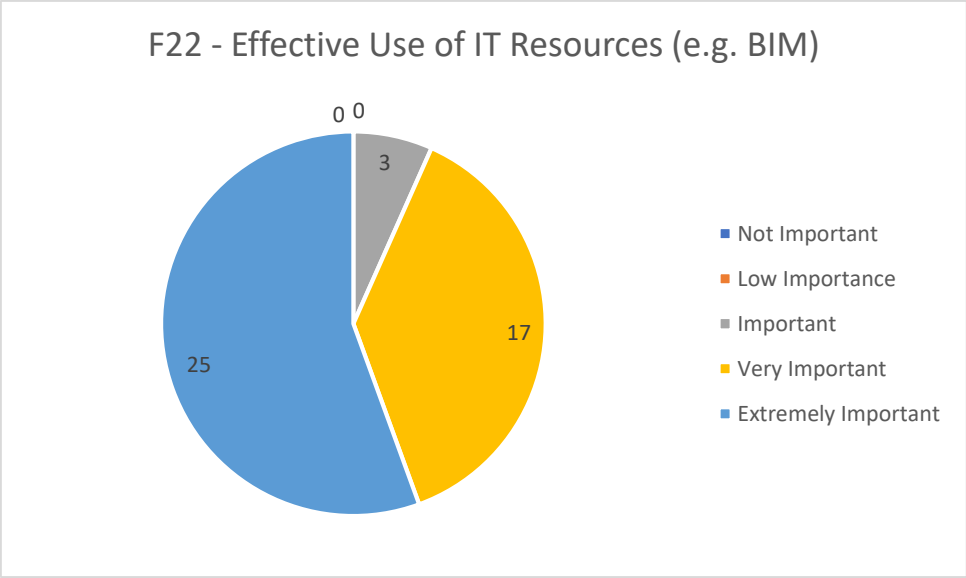
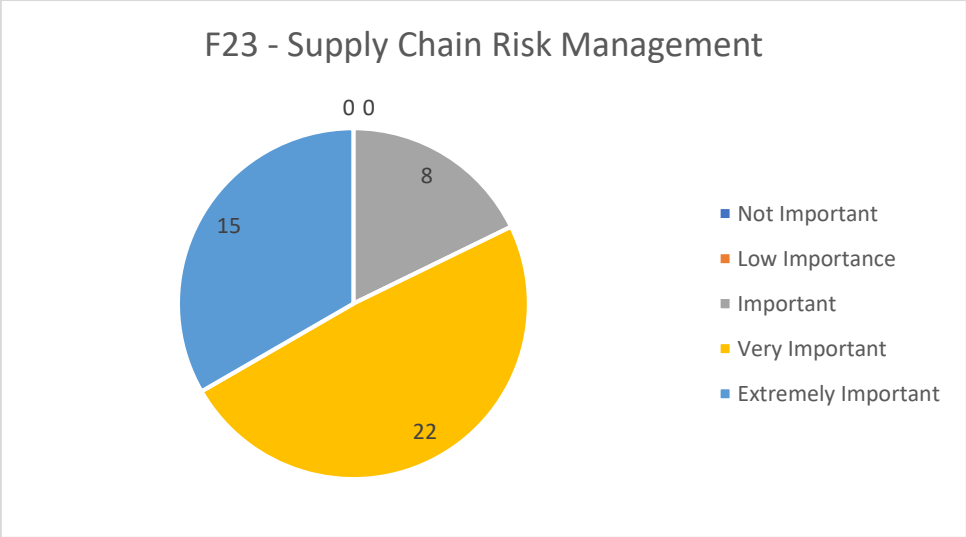
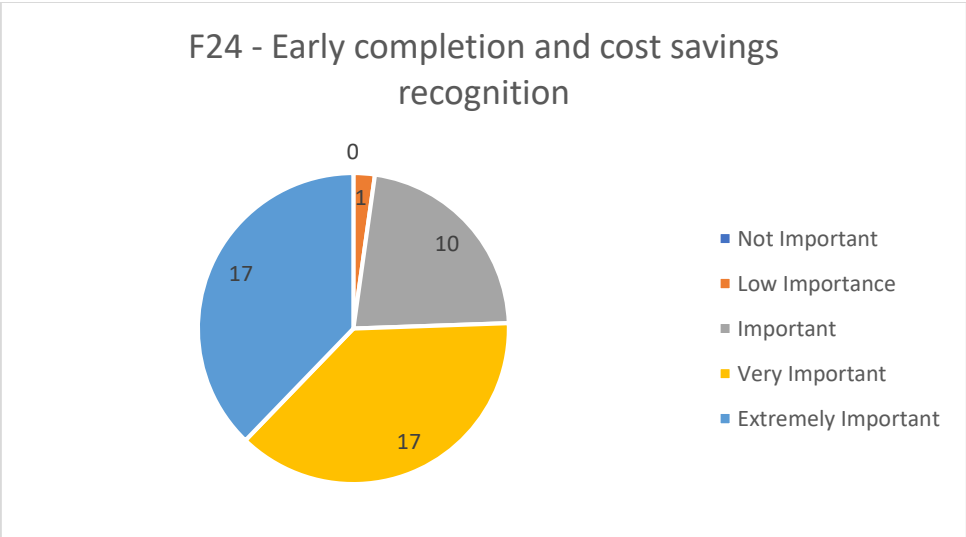
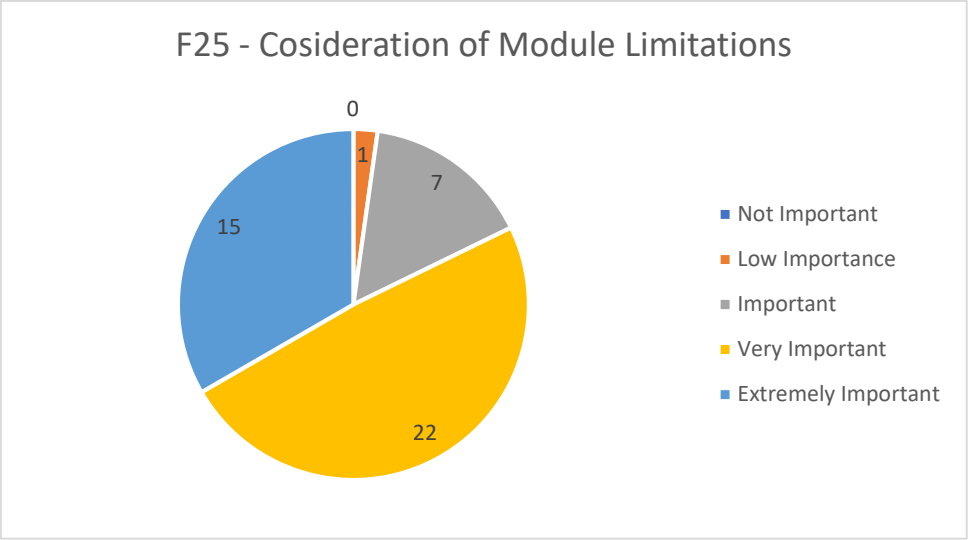
Very Important
Extremely Important


F21 - Appreciation of the Impact of Early Decisions
0
1
4
15
25
Not Important
Low Importance
Important
Very Important
Extremely Important


F22 - Effective Use of IT Resources (e.g. BIM)
0
0
3
17
25
Not Important
Low Importance
Important
Very Important
Extremely Important


F23 - Supply Chain Risk Management
0
0
8
15
22
Not Important
Low Importance
Important
Very Important
Extremely Important


F24 - Early completion and cost savings recognition
0
1
10
17
17
Not Important
Low Importance
Important
Very Important
Extremely Important


F25 - Cosideration of Module Limitations
0
1
7
15
22
Not Important
Low Importance
Important
Very Important
Extremely Important

B. DEMATEL Survey for PSFs

B.1 Sample DEMATEL for PSFs Questionnaire

DEMATEL Survey Questionnaire

Introduction:

This questionnaire is for collecting data to be used in M.Sc. thesis research paper about finding the critical success factors for implementing Off-Site/ Modular Construction projects in the UAE.

The **De**cision **Ma**king **T**rial and **E**valuation **L**aboratory (DEMATEL) is proposed as it is a powerful Multi-Criteria Decision Making Technique.

Background Information:

In the survey the participants need to rate the impact of each factor on the other on the following scale:

Rating	Meaning
1	No Influence
2	Very Low Influence
3	Moderate Influence
4	High Influence
5	Very High Influence

The respondent needs to rate the relationship The Principal Success Factors **(PSFs)**, the PSFs are made as a grouping between a few other Critical Success Factors **(CSFs)** as shown below:

CSF/ PSF No.	CSF/ PSF
PSF1	**Project Coordination & Quality Management**
CSF1	Good Communication and Collaboration between all stakeholders
CSF5	Effective Use of IT Resources (e.g. BIM)
CSF9	On-site and Off-site Coordination
CSF13	Continuous Improvement
PSF2	**Human Resources Management**
CSF2	Fabricator Experience in Modules
CSF6	Experience and Knowledge of Key players
CSF12	Manpower and Technicians' Experience
CSF22	Availability of Skilled Technicians and supervisors
PSF3	**Design & Specification Control & Management**
CSF3	Robust drawing specifications and early design freeze
CSF8	Standardization for mass production
CSF11	Alignment of Modules and Project Requirements
CSF23	Consideration of Module Limitations
PSF4	**Procurement Control**
CSF10	Supply Chain Coordination and Control
CSF15	Suitable Procurement and Contracting Strategies
CSF16	Availability of Local transportation infrastructure
CSF21	Supply Chain Risk Management

CSF/ PSF No.	CSF/ PSF
PSF5	**Early Commitment & Engagement**
CSF4	Early Advice from Experts and Professionals
CSF17	Availability of Key members at the earliest stages
CSF19	Early Involvement of Suppliers and Fabricators
PSF6	**Schedule Planning & Stakeholder Management**
CSF7	Precise project planning and control
CSF18	Effective coordination and management of stakeholders
CSF25	Top Management Support and Involvement in Decision Making
PSF7	**Cost Control & Management**
CSF14	Early Economic Analysis & Scope Definition
CSF20	Appreciation of the Impact of Early Decisions
CSF24	Early completion and cost savings recognition

DEMATEL survey:

Please note that in the survey, the participant has to rate the impact of the row on the column. refer to the below table for an example:

Impact

Influence (i \ j)	PSF1	PSF2	…	PSFj
PSF1		m_{12}	…	m_{1j}
PSF2	m_{21}		…	m_{2j}
⋮	⋮	⋮		⋮
PSFi	m_{i1}	m_{i2}	…	

- In the Green Highlighted cell (m_{12}) you need to rate the impact of PSF1 on PSF2
- In the Yellow Highlighted cell (m_{21}) you need to rate the impact of PSF2 on PSF1
- Please note that these values do not have to the same as sometimes the impact is one directional
- Please note that cells in dark blue are not to be filled

Please find in the next sheet the DEMATEL Questionnaire:

Participant Information:

Name:	
Position:	
Total Experience in Construction:	
Total Experience with Offsite/ Modular Construction:	

		Project Coordination & Quality Management	Human Resources Management	Design & Specification Control & Management	Procurement Control	Early Commitment & Engagement	Schedule Planning & Stakeholder Management	Cost Control & Management
		PSF1	**PSF2**	**PSF3**	**PSF4**	**PSF5**	**PSF6**	**PSF7**
Project Coordination & Quality Management	**PSF1**							
Human Resources Management	**PSF2**							
Design & Specification Control & Management	**PSF3**							
Procurement Control	**PSF4**							
Early Commitment & Engagement	**PSF5**							
Schedule Planning & Stakeholder Management	**PSF6**							
Cost Control & Management	**PSF7**							

B.2. DEMATEL for PSFs Responses

Survey 1

		Project Coordination & Quality Management	Human Resources Management	Design & Specification Control & Management	Procurement Control	Early Commitment & Engagement	Schedule Planning & Stakeholder Management	Cost Control & Management
		PSF1	**PSF2**	**PSF3**	**PSF4**	**PSF5**	**PSF6**	**PSF7**
Project Coordination & Quality Management	**PSF1**		2	3	3	3	2	3
Human Resources Management	**PSF2**	2		3	2	3	3	3
Design & Specification Control & Management	**PSF3**	4	4		4	4	3	4
Procurement Control	**PSF4**	2	3	3		4	3	4
Early Commitment & Engagement	**PSF5**	3	2	2	2		3	2
Schedule Planning & Stakeholder Management	**PSF6**	3	3	4	4	4		4
Cost Control & Management	**PSF7**	1	2	1	2	2	2	

Rating	Meaning
1	No Influence
2	Very Low Influence
3	Moderate Influence
4	High Influence
5	Very High Influence

Survey 2

		Project Coordination & Quality Management	Human Resources Management	Design & Specification Control & Management	Procurement Control	Early Commitment & Engagement	Schedule Planning & Stakeholder Management	Cost Control & Management
		PSF1	**PSF2**	**PSF3**	**PSF4**	**PSF5**	**PSF6**	**PSF7**
Project Coordination & Quality Management	**PSF1**		2	5	4	4	5	3
Human Resources Management	**PSF2**	5		2	3	4	2	3
Design & Specification Control & Management	**PSF3**	5	3		5	3	5	4
Procurement Control	**PSF4**	4	2	5		5	5	5
Early Commitment & Engagement	**PSF5**	4	5	4	5		4	3
Schedule Planning & Stakeholder Management	**PSF6**	4	4	5	5	3		2
Cost Control & Management	**PSF7**	2	3	2	4	2	2	

Survey 3

		Project Coordination & Quality Management	Human Resources Management	Design & Specification Control & Management	Procurement Control	Early Commitment & Engagement	Schedule Planning & Stakeholder Management	Cost Control & Management
		PSF1	**PSF2**	**PSF3**	**PSF4**	**PSF5**	**PSF6**	**PSF7**
Project Coordination & Quality Management	**PSF1**		4	5	4	3	3	4
Human Resources Management	**PSF2**	4		4	4	4	4	4
Design & Specification Control & Management	**PSF3**	3	3		5	5	5	5
Procurement Control	**PSF4**	2	2	3		4	3	5
Early Commitment & Engagement	**PSF5**	3	3	3	3		3	4
Schedule Planning & Stakeholder Management	**PSF6**	4	4	4	4	4		4
Cost Control & Management	**PSF7**	5	4	4	5	3	5	

Survey 4

		Project Coordination & Quality Management	Human Resources Management	Design & Specification Control & Management	Procurement Control	Early Commitment & Engagement	Schedule Planning & Stakeholder Management	Cost Control & Management
		PSF1	**PSF2**	**PSF3**	**PSF4**	**PSF5**	**PSF6**	**PSF7**
Project Coordination & Quality Management	**PSF1**		1	2	3	2	3	4
Human Resources Management	**PSF2**	4		3	2	3	3	2
Design & Specification Control & Management	**PSF3**	4	1		4	2	3	2
Procurement Control	**PSF4**	4	1	5		4	4	5
Early Commitment & Engagement	**PSF5**	2	3	3	4		4	3
Schedule Planning & Stakeholder Management	**PSF6**	1	3	5	4	1		4
Cost Control & Management	**PSF7**	1	3	5	2	2	3	

Survey 5

		Project Coordination & Quality Management	Human Resources Management	Design & Specification Control & Management	Procurement Control	Early Commitment & Engagement	Schedule Planning & Stakeholder Management	Cost Control & Management
		PSF1	**PSF2**	**PSF3**	**PSF4**	**PSF5**	**PSF6**	**PSF7**
Project Coordination & Quality Management	**PSF1**		4	5	5	5	3	4
Human Resources Management	**PSF2**	4		1	2	1	2	3
Design & Specification Control & Management	**PSF3**	5	1		5	5	3	5
Procurement Control	**PSF4**	5	3	5		5	5	5
Early Commitment & Engagement	**PSF5**	5	2	4	4		3	4
Schedule Planning & Stakeholder Management	**PSF6**	4	3	4	5	4		4
Cost Control & Management	**PSF7**	2	1	4	5	4	4	

Survey 6

		Project Coordination & Quality Management	Human Resources Management	Design & Specification Control & Management	Procurement Control	Early Commitment & Engagement	Schedule Planning & Stakeholder Management	Cost Control & Management
		PSF1	**PSF2**	**PSF3**	**PSF4**	**PSF5**	**PSF6**	**PSF7**
Project Coordination & Quality Management	**PSF1**		4	5	3	3	3	1
Human Resources Management	**PSF2**	1		3	1	3	5	4
Design & Specification Control & Management	**PSF3**	1	2		5	5	3	3
Procurement Control	**PSF4**	3	1	3		3	3	4
Early Commitment & Engagement	**PSF5**	1	3	5	2		2	1
Schedule Planning & Stakeholder Management	**PSF6**	2	2	4	3	2		3
Cost Control & Management	**PSF7**	3	1	4	4	1	3	

Survey 7

		Project Coordination & Quality Management	Human Resources Management	Design & Specification Control & Management	Procurement Control	Early Commitment & Engagement	Schedule Planning & Stakeholder Management	Cost Control & Management
		PSF1	**PSF2**	**PSF3**	**PSF4**	**PSF5**	**PSF6**	**PSF7**
Project Coordination & Quality Management	**PSF1**		1	4	2	4	5	3
Human Resources Management	**PSF2**	4		4	4	3	4	1
Design & Specification Control & Management	**PSF3**	4	1		5	3	4	3
Procurement Control	**PSF4**	1	1	1		1	3	1
Early Commitment & Engagement	**PSF5**	4	1	5	3		4	1
Schedule Planning & Stakeholder Management	**PSF6**	3	1	3	3	4		1
Cost Control & Management	**PSF7**	1	1	1	1	1	1	

Survey 8

		Project Coordination & Quality Management	Human Resources Management	Design & Specification Control & Management	Procurement Control	Early Commitment & Engagement	Schedule Planning & Stakeholder Management	Cost Control & Management
		PSF1	**PSF2**	**PSF3**	**PSF4**	**PSF5**	**PSF6**	**PSF7**
Project Coordination & Quality Management	**PSF1**		2	3	3	4	4	3
Human Resources Management	**PSF2**	5		5	1	3	3	1
Design & Specification Control & Management	**PSF3**	5	1		1	2	3	4
Procurement Control	**PSF4**	4	1	1		4	1	5
Early Commitment & Engagement	**PSF5**	5	4	5	4		2	1
Schedule Planning & Stakeholder Management	**PSF6**	5	4	1	4	2		1
Cost Control & Management	**PSF7**	1	1	3	4	1	2	

Survey 9

		Project Coordination & Quality Management	Human Resources Management	Design & Specification Control & Management	Procurement Control	Early Commitment & Engagement	Schedule Planning & Stakeholder Management	Cost Control & Management
		PSF1	**PSF2**	**PSF3**	**PSF4**	**PSF5**	**PSF6**	**PSF7**
Project Coordination & Quality Management	**PSF1**		2	3	4	1	3	4
Human Resources Management	**PSF2**	2		2	2	4	2	4
Design & Specification Control & Management	**PSF3**	4	2		3	4	3	5
Procurement Control	**PSF4**	1	2	2		2	2	5
Early Commitment & Engagement	**PSF5**	2	4	4	2		5	3
Schedule Planning & Stakeholder Management	**PSF6**	4	4	3	3	4		2
Cost Control & Management	**PSF7**	2	2	1	2	2	2	

C. DEMATEL for CSFs Response

Survey10		Good Communication and Collaboration between all stakeholders	Fabricator Experience in Modules	Robust drawing specifications and early design freeze	Early Advice from Experts and Professionals	Effective Use of IT Resources (e.g. BIM)	Experience and Knowledge of Key players	Precise project planning and control	Standardization for mass production	On-site and Off-site Coordination	Supply Chain Coordination and Control	Alignment of Modules and Project Requirements	Manpower and Technicians' Experience	Continuous Improvement	Early Economic Analysis & Scope Definition	Suitable Procurement and Contracting Strategies	Availability of Local transportation infrastructure	Availability of Key members at the earliest stages	Effective coordination and management of stakeholders	Early Involvement of Suppliers and Fabricators	Appreciation of the Impact of Early Decisions	Supply Chain Risk Management	Availability of Skilled Technicians and supervisors	Cosideration of Module Limitations	Early completion and cost savings recognition	Top Management Support and Involvement in Decision Making
		CSF1	**CSF2**	**CSF3**	**CSF4**	**CSF5**	**CSF6**	**CSF7**	**CSF8**	**CSF9**	**CSF10**	**CSF11**	**CSF12**	**CSF13**	**CSF14**	**CSF15**	**CSF16**	**CSF17**	**CSF18**	**CSF19**	**CSF20**	**CSF21**	**CSF22**	**CSF23**	**CSF24**	**CSF25**
Good Communication and Collaboration between all stakeholders	**CSF1**		2	5	3	3	2	5	4	5	3	3	1	4	2	3	1	1	5	1	1	3	1	2	2	4
Fabricator Experience in Modules	**CSF2**	3		3	5	2	2	3	4	3	2	4	2	5	2	3	1	2	3	1	2	3	4	4	3	1
Robust drawing specifications and early design freeze	**CSF3**	2	1		2	3	1	5	5	5	4	4	1	5	5	4	1	1	3	3	4	3	1	4	4	3
Early Advice from Experts and Professionals	**CSF4**	2	2	4		4	2	2	3	3	4	4	1	3	4	4	1	2	4	4	3	3	2	4	4	2
Effective Use of IT Resources (e.g. BIM)	**CSF5**	3	1	4	1		1	4	4	4	1	2	1	3	4	3	1	2	1	1	4	2	1	3	4	1
Experience and Knowledge of Key players	**CSF6**	4	3	4	3	4		4	3	4	4	4	2	4	4	4	1	3	4	1	4	4	1	3	4	2
Precise project planning and control	**CSF7**	2	2	2	4	2	2		3	4	5	3	2	5	5	5	1	4	4	5	5	4	2	2	5	3
Standardization for mass production	**CSF8**	1	1	5	2	2	2	4		2	3	5	1	4	4	4	1	1	2	1	4	4	1	3	4	1
On-site and Off-site Coordination	**CSF9**	4	2	4	3	3	2	4	3		5	3	1	5	2	5	1	1	5	3	4	4	1	2	4	3
Supply Chain Coordination and Control	**CSF10**	2	1	1	3	2	1	2	1	2		1	1	2	1	4	1	1	2	2	2	5	1	2	3	1
Alignment of Modules and Project Requirements	**CSF11**	1	1	4	1	3	1	4	5	4	4		1	4	3	5	1	1	1	2	4	4	1	3	4	2
Manpower and Technicians' Experience	**CSF12**	2	3	2	4	2	4	2	2	2	2	1		5	3	3	1	3	2	3	4	2	3	2	3	4
Continuous Improvement	**CSF13**	4	2	3	4	2	2	2	3	3	4	4	1		3	2	1	2	2	4	3	3	2	3	3	3
Early Economic Analysis & Scope Definition	**CSF14**	1	1	4	3	2	2	4	2	1	4	2	1	2		4	1	3	3	3	5	3	3	1	4	3
Suitable Procurement and Contracting Strategies	**CSF15**	2	2	2	2	2	2	3	2	3	5	2	2	3	3		1	2	3	3	3	5	2	2	3	2
Availability of Local transportation infrastructure	**CSF16**	1	1	1	2	2	1	3	2	2	4	1	1	1	2	4		1	1	2	4	5	1	2	2	2
Availability of Key members at the earliest stages	**CSF17**	3	2	3	3	3	3	3	2	3	3	3	2	3	3	3	1		3	3	4	3	2	2	4	3
Effective coordination and management of stakeholders	**CSF18**	3	1	3	1	1	1	2	1	2	2	2	1	2	3	3	1	1		2	3	2	2	1	3	2
Early Involvement of Suppliers and Fabricators	**CSF19**	2	1	3	3	2	1	3	3	3	5	4	2	3	4	4	1	2	3		3	5	1	3	4	2
Appreciation of the Impact of Early Decisions	**CSF20**	2	1	2	3	2	1	4	1	3	4	2	2	3	5	5	1	3	2	3		4	2	2	5	1
Supply Chain Risk Management	**CSF21**	2	1	2	2	2	1	2	2	2	5	2	1	3	4	4	1	1	1	2	3		1	2	4	2
Availability of Skilled Technicians and supervisors	**CSF22**	3	2	2	2	2	3	2	4	2	2	2	3	3	4	4	1	1	1	1	4	1		1	3	2
Cosideration of Module Limitations	**CSF23**	1	1	4	3	3	1	4	3	2	4	4	1	4	3	4	1	1	1	2	2	4	1		4	1
Early completion and cost savings recognition	**CSF24**	2	1	2	3	2	1	2	2	2	3	2	1	2	4	4	1	2	1	3	3	3	2	2		1
Top Management Support and Involvement in Decision Making	**CSF25**	4	2	4	4	2	2	5	1	4	5	2	1	4	5	4	1	1	4	4	3	4	5	2	5	