Use of Agile project management in the augmentation of construction prefabrication effort

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THESIS ACCEPTANCE CERTIFICATE

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AUTHOR'S DECLERATION

I, Muhammad Awais Ahmed hereby state that my MS Thesis titled "Use of Agile project management in the augmentation of construction prefabrication effort" is my own work and has not been submitted previously by me for taking any degree from this National University of Sciences and Technology (NUST) or anywhere else in the country/ world.

At any time if my statement is found to be incorrect even after I graduate, the university has the right to withdraw my MS Degree.

Name of Student: _____

Date: _____

This thesis is dedicated to my loving family, affectionate friends, and my honorable teachers.

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ABSTRACT

Construction industry is one of the major contributors of economic growth and development all over the globe. Due to the complex nature of the construction projects and the involvement of a large number of manpower construction projects all over the world are marred with inconsistent results and inefficient products. Keeping this in mind construction industry has developed a new way forward in order to move towards a more automated approach of offsite construction prefabrication which can help move the construction industry in a new era. Application of agile project management in the field of construction prefabrication can lead to even better results if implemented properly. Keeping this in mind this research will focus on the implementation of agile project management in the field of construction prefabrication. The research in question aims to achieve this goal by detailed literature review on the attributes of agile project management which can be utilized in order to augment the construction prefabrication effort. Literature review is also done on the critical success factors of construction prefabrication. A questionnaire survey is conducted on the attributes of agile project management as well as critical success factors of construction prefabrication effort. Exploratory factor is applied on the attributes of agile project management and the attributes of agile project management are grouped into two main categories for further research on the topic. This study concludes that attributes of agile project management have strong positive correlations with the critical success factors of construction prefabrication. The study done in this regard can be used as a stepping stone for further research on the topic and can lead to further research in project management areas like procurement and R&D as well.

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CHAPTER 1: INTRODUCTION

Construction industry is on the most significant contributors to the economic growth of any country (Kopsida and Vela 2015), Research shows us that performance inconsistency and inefficiency of construction projects is growing rapidly over time (Yeung et al. 2013).It has been observed that an overall 90% of the construction projects face time and cost overruns besides facing a number of other problems as well (Moon et al. 2018).

Use of technology and innovative techniques has led to the improvement of a number of different industries. A number of benefits of applying technology and innovative techniques have been reported which include cost effectiveness, reduction of time and decrease in the wastage produced. Despite strong interest in improving the efficiency of the construction industry. The work done in this regard is not up to the mark. This has led to reduced efficiency of the overall construction projects. Application of new and innovative project management techniques like agile project management instead of the commonly used traditional project management method can lead to improved results. Same is the case with construction prefabrication that successful implementation of it can lead to increased efficiency as well as reduced construction wastes as well (Tan et al. 2019)

1.1 Why Prefabrication Should Be Used Instead of The Traditional Approach?

Traditional project management has been in use for a long time now. Over the course of time complexity evolved in construction projects. The main issues which were facing the construction industry using traditional construction approach are being detailed here as follows.

Investigation was conducted by Kuenzel et al. in 2016 which detailed the fact that as close as 90% of the construction projects which were analyzed in the study were having a number of different

co-ordination problems which leads to unsuccessful project management which has exceeded project deadlines as compared to their original deadline. (Kuenzel 2016). In the same year of 2016 research was conducted by Oesterreich et al. which concluded that the fundamental cause of failure for construction projects was the insufficient commitment of stakeholders towards their construction project. (Oesterreich 2016)

Investigation conducted by Howel et al. has detailed the fact that a number of different planning issues, complications in the overall project organization and the number of different stakeholder agreements has led to extensive delays in the completion of construction projects which also leads to increase in the project budget, increase in the overall project complexity as well as constant variation orders from client's end. (Howell, Ballard and Tommelein 2011)

It was determined by Hoffman et al in the year 2007 that 72% of the 332 public facility projects being conducted in the US were delivered late as compared to their original deadline for project completion. 47% of these projects were completed less than 4 months after their original deadline. (Hoffman 2007)

An analysis was conducted by the German Federal Ministry of Construction for the years between 2000 and 2015 and it was found that the projects had fairly exceeded costs as well as overall exceeded timelines for a total of 300 building projects which had a cost of more than 10m EUROs. Only 65% of the total projects had achieved their scheduled project timeline. (Century 2008)

An investigation was conducted by Assaf and El-Hejji in the year 2016 which evaluated that 59% of the total 76 evaluated projects in Saudi Arabia were considered delayed at the end of their project lifecycle. (Al-Hejji 2006)

Another study was conducted by Braimah in the year 2014 which provided the results that weak design, poor project planning, ineffective site management and project control, inexperienced

contractor experience, contractor payment problems, in availability of equipment are the primary causes for delays in the construction projects. The main problems which were being faced by and large by the construction industry included lack of productivity in the overall construction process. Reduction in the overall pace of progress on construction projects. The waste produced in such a construction industry is also huge and has severe consequences for long lasting nature.

The number of accidents is also huge, and this is leading to a number of different fatalities on the construction sites all over the world. Another major problem which is a cause of worry to all investors which are looking to spend their hard-earned money in the field of construction is the excessive cost over runs which have marred the construction industry as a whole.

Finally, the construction industry of today is facing a number of different quality control issues which leads us to construction projects of inferior quality. Keeping in mind the major issues which were faced by the traditional construction approach. Construction professionals are moving towards a relatively new and innovative approach of construction prefabrication which not only tries to mitigate the problems faced by the construction industry by and large but rather also help us to improve on the major aspects of any construction project as well. (Shen 2020)

1.2 Problems in Planning and Implementation of Construction Prefabrication

Since the usage of construction prefabrication has been done in the mainstream construction industry, the planning and implementation effort of construction prefabrication has led to a number of problems being faced by the early adopters. This is widely due to the fact that by and large construction industry all over the world is not used to the new and proactive approach of the construction prefabrication effort. (Braimah 2014)

Keeping this in mind the major barriers which were faced are discussed here. Lack of domestic-oriented BIM tools for the local population. Increased workload for model development of the

entire BIM ecosystem. Negative attitude towards working collaboratively in the construction industry. Lack of a well-established BIM-based workflow for the construction industry. Immature dispute resolution mechanism for BIM implementation in the construction industry. Lack of professional interactivity in the workplace/ construction site. Lack of research and resources being allocated to BIM implementation. Cost and time required for training professionals. Excessive cost for BIM experts and tools. Increased design costs for BIM integration. Lack of BIM standards for the construction industry. Lack of standard form of contract for BIM implementation. (Tan Tan, 2019)

1.3 Studies Conducted in Support of Construction Prefabrication

There have been several different studies which have effectively utilized and assessed the need for construction prefabrication effort. Results obtained from some of these research have been discussed here in detail in order to assess the work already done in the field of construction prefabrication.

According to F Shadram, companies have worked in recent years to industrialize their manufacturing processes, to introduce prefabrication by standardization of their products and to work in collaborative networks. Results show that the adaptation of prefabricated building mainly depends on factors such as labor shortage, labor cost, housing demand, building process efficiency, weather, as well as reduction of waste material and energy consumption. (F Shadram 2016)

As per the work of J Zhang the construction industry faces challenges such as low productivity, high construction safety risk, and poor environmental performance. Constant modifications of the project requirements coupled with occurring problems in defining the original product requirement causes cost overruns and schedule delay and lowers the product quality. As a countermeasure,

agile project management was created which can be coupled with agile project management in order to effectively reduce the problems being faced in the construction industry. (J Zhang 2020)

According to the study conducted by YR Chen, prefabrication can be gradually introduced to rural areas. However, the implementation of prefabrication in rural areas is impacted by various factors. Therefore, twelve factors which have different influence on the prefabrication implementation were identified. These factors were classified into internal and external groups and were considered as the base for conducting SWOT analysis in prefabrication implementation. (YR Chen 2017)

1.4 Research Gap

In the past works examined, there have been a number of different research which are done in order to implement agile project management in different fields and industries. This trend is being spearheaded by the implementation of agile project management in the technology sector. Overtime researchers have used the success shown by the implementation of agile project management in the technology sector to look for ways this innovative project management technique can be implemented in the construction industry.

In this regard the shortcomings of the use of traditional project management approach are expected to be overcome with the implementation of agile project management technique in favor of traditional project management approach. Same is the case with the implementation of construction prefabrication instead of the traditional construction approach. A number of research is available on this topic as well.

There is no explicit research on the implementation of agile project management in construction prefabrication. Research is available on scrum is implementation in the construction design phase

which can be used as a basis for implementation of agile project management in construction prefabrication.

1.5 Research Question

The problems identified earlier regarding the shortcomings of traditional project management approach can be solved with the implementation of new and innovative techniques of agile project management leading to better results. The successful implementation of agile project management will be subject to the benefits which can be obtained from the various attributes of agile project management.

Similarly, the success of any construction prefabrication project will be subject to achieving the critical success factors of construction prefabrication projects. Following questions will help us achieve the final goal for our research in question:

- What are the attributes of agile project management which can lead to success in any construction project and can provide better results than traditional project management approach.
- What are the critical success factors of construction prefabrication effort which can lead to the overall project success and provide better results as compared to a traditional construction project.
- How can we utilize agile project management in increasing the effectiveness of construction projects.

1.6 Research Idea

The main purpose of conducting this research is to attain better results from the construction projects. Based on the discussion earlier this can be done by replacing the traditional project

management approach with a new and innovative project management approach like agile project management. Similarly, the traditional construction approach is not providing the requisite results and new and innovative technologies and processes are required in order to ensure project success. Construction prefabrication can prove to be the way forward in order to achieve better results from the construction projects. This research will focus on identifying and assessing attributes of agile project management which can lead to project success.

1.7 Problem Statement

In the previous studies, the development of a framework which utilizes the agile project management is used in order to augment the design phase of a construction project. There is no explicit research done which utilizes agile project management in order to augment the overall construction prefabrication process.

1.8 Objectives

Construction Industry is utilizing the traditional project management approach and the traditional construction approach which is not providing the required results as discussed in the previous studies. Keeping this in mind the research in question will focus on the implementation of agile project management instead of the traditional project management approach. As it is fairly evident from some of the studies discussed earlier that implementation of agile project management will have fruitful results in the construction prefabrication projects. This research will aspire to achieve the following objectives detailed below:

- To determine attributes of agile project management which are critical for success in construction prefabrication.
- Identify critical success factors of construction prefabrication projects.

- Validate the attributes of agile project management using exploratory factor analysis by better understanding the underlying correlations between attributes.

Composition Of Thesis

The thesis is organized in five chapters with chapter 1 covering an introduction to implementation of agile project management in construction prefabrication effort. Chapter 2 covers literature review. Chapter 3 covers methodology used in the research and chapter 4 covers results and analysis. The final (5th) chapter presents the conclusions and recommendations.

CHAPTER 2: LITERATURE REVIEW

2.1 Techniques and Methods of Construction Project Management

Traditional project management is a linear process and takes relatively more time and does not cater for effective change management during the project lifecycle. Agile project management is an iterative process and caters for effective change management during the entire project lifecycle. The main differences between the traditional and agile approach are provided in the table 2.1 below:

Table 2.1 Differences between traditional and agile project management approach.

Characteristics	Traditional Approach	Agile Approach
Organizational structure	Linear	Iterative
Scale of projects	Large scale projects	Small and medium scale projects
Development model	Project lifecycle	Evolutionary delivery
Change management	Does not support change management during project lifecycle	Can effectively handle change management during iterative process.
Test documentation	Comprehensive test planning	Tests are planned one sprint at a time

2.2 Problems in Construction Planning

To eradicate problems in the overall construction planning process the first step is to identify the major problems being faced in the overall construction planning process. In this regard the major problems in construction planning are as follows:

2.2.1 Inaccurate construction project risk management

Construction projects are often risky businesses and involve a lot of financial risk. To better safeguard the clients of construction projects from the inherent risk the construction project managers put in a lot of checks to reduce the long-term risks incurred by construction projects. But in this regard the short-term risks are kept out of calculation which can lead to financial loss for a construction project.

This risk is rather amplified by the unreliable subcontractors, project scheduling and work front problems, Number of change/variation orders. If these issues are ignored over the course of the construction project, then these projects will be amplified and can cause significant delays and financial problems for the project.

2.2.2 Lack of organizational structure in construction projects

There are several major construction companies all over Pakistan which are listed as no limit contractors by the PEC. But when we look closely at the working of such major construction companies, we will get to know that the overall working of such major contractors is still rather very unorganized and haphazard to say the least.

All such construction companies are working on a project basis which leads to a number of different teams on different projects. Once such projects are completed most of the time the teams are disbanded or transferred into different roles. In this regard the central organizational structure remains absent and can cause a lot of different problems over the lifetime of a construction company.

2.2.3 Poor Communication

Effective communication is rather a very important tool in the lifetime of any professional. Effective communication is rather important in the lifetime of construction projects which are taking place in a rather projectized environment. In the absence of clear and effective communication such projects cannot be completed effectively. Important tasks which cannot be communicated effectively to the project team will not yield the same results and rather lead to a number of problems. In this regard project managers set up several different meetings and notice boards in order to make sure that guidelines and instructions are passed down onto the project team effectively in order to make sure that the project is completed successfully.

2.2.4 Unrealistic project expectations and timelines

Generally, construction projects are very costly and time taking endeavors which lead to the clients asking for very big asks which are not even realistic to say the least. In this regard it is the task of construction project managers to manage the client's expectations effectively and to make sure that the project is being done efficiently and the expectations of all project stakeholders are kept in check as well. Commonly the clients are asking for a reduced project timeline which can lead to a number of different financial and work front problems which can lead to the failure of the project as well.

2.2.5 Delay in the cash flow into the construction project

Any major construction project relies heavily on the running bills on site to pay off their liabilities. But the billing and financial matters of construction projects are being done by outdated methods which leads to the delay in the project running bills to the contractors which in turn leads to the delay in the payments of material suppliers and subcontractors etc. This can badly impact on the

cash flow of any running project and can overall lead to an increase in the number of problems of the construction project.

2.2.6 Limited skills and ineffective management skills

The construction industry as a whole is a very labor-intensive industry and can lead to the overall complexity of construction projects. This is owing to the fact that the overall number of uneducated labor can lead to a number of different problems if the labor is not managed effectively and in order to manage labor effectively efficient project managers are needed in order to complete construction projects effectively.

2.3 Construction Prefabrication as An Alternative

In this section discussion will be done on how we can utilize construction prefabrication as an alternative to the problems currently being faced on construction projects. In this section discussion will be done on the application of construction prefabrication as an alternate approach to undertake construction projects.

2.3.1 Definition of construction prefabrication

Prefabricated construction, also commonly known as “Prefab” is a rather important method of construction in which components are usually manufactured off site in order to be arranged or assembled on site. This is done after the transportation of the components on site. This rather new method of construction is used in order to make sure that the project is being developed with relatively lower risk and cost. Major benefits of construction prefabrication are listed below.

2.3.2 Major benefits of construction prefabrication

Being a civil contractor, it is highly problematic for such an entity to procure and arrange skilled and unskilled labor for construction projects. This problem is more than prevalent in the developed countries where most of the population is well educated and looks toward better opportunities and well-paying jobs rather than to work in the construction sector. Construction prefabrication provides an alternative to the problem in question and reduces the need for labor on the construction sites by effectively promoting off site manufacturing and assembly and reducing on site activity.

The overall process of construction prefabrication leads to the construction project as a whole being transformed into an operational process in which operations are to be repeated over and over again in order to produce or manufacture modules to be used in the construction projects. In this regard the labor can be trained to increase effectively also economies of scale come into action and can reduce the overall cost of procurement on such construction projects as well which leads to the overall reduction in the cost of construction projects.

Using the construction prefabrication technique, the construction projects can effectively be used to reduce the timeline of construction projects which can also in turn reduce the construction cost of indirect nature as well. It is common knowledge that if any product is being manufactured at any production facility machined plant than in that case the product can be expected to be of a high quality and the quality control of such a facility in question will be expected to only produce high quality products as compared to any construction project where timelines are very stringent and the product being developed is expected to have relatively poor quality control standards.

Offsite construction activities can be calibrated in such a way as to reduce the harmful emissions being released from such an offsite construction facility. The removal of waste from such a facility

can also be calibrated in order to preserve the local flora and fauna in order to make sure that the product being developed is of a higher quality. It must also be noted that such an off-site facility can help increase the overall recycling effort as well.

Construction projects in the developing or the underdeveloped world are known to have ineffective and problematic construction safety and security networks on site which can lead to a number of different fatal and non-fatal accidents on site. In case such incidents are reduced, then in such a scenario we will have to utilize the construction prefabrication process to the maximum.

Off-site construction techniques like construction prefabrication can lead to a number of different solutions and can lead to an increase in the overall flexibility of the construction projects. This leads to an effective solution to the rigid nature of the construction projects which are mostly linear in nature and can lead to the overall delay in the completion of a construction project as a whole.

2.3 How Planning in Construction Prefabrication Is Inherently Different

The main goal of construction projects of all project stakeholders is to complete the projects within the constraints of time, cost, and scope. Prefabrication is rather very effective in this regard because it provides an alternative to complete the construction projects in relatively less time as compared to traditional project delivery. This can be made possible only through the utilization of effective project planning. In this regard advanced construction planning tools like CPM, PERT, Gantt charts should be utilized to the maximum. The activity structures are to be utilized to the maximum in order to make sure that the construction prefabrication effort is being executed successfully.

In this regard dependency structures matrix (DSM) is an effective alternative approach which is being effectively utilized in the manufacturing field and can also be used in the field of construction prefabrication as well. This effective technique is being used to reduce the shortcomings of the

traditional project planning effort and can lead to an increase in the effectiveness of construction project effort.

2.4 AGILE PROJECT MANAGEMENT

2.4.1 What is agile project management?

One of the most innovative method for construction project management is agile project management which is now being used extensively in most developed countries. Agile project management is an iterative approach of project delivery throughout the lifecycle of that specific project. Agile project management is mainly composed of iterative approaches which are mostly being used in software development projects extensively. This small incremental iteration is done using the different tools which are at the disposal of the project team. The focus of agile project management is to promote velocity and adaptability of agile project management which can help us adjust in the overall linear path of the project lifecycle. Another main focus of agile project management is to release the project benefits throughout the project lifecycle.

2.4.2 Principles of agile project management

The major principle behind agile project management is to concentrate on the empowerment of the project team as well as their interactions which will lead to early interactions as well as constant delivery of value to the project enterprise. Main focus of agile project management is to focus on the delivery of maximum value against the different business priorities in which allowance has been made for time and budget especially in the case when the project team is looking to deliver the maximum reward against the risks incurred against the project.

The main principle of agile project management includes that the project is broken down into smaller and smaller pieces which have to be prioritized by the project team on the basis of their

relative importance in the project. This drive is augmented by collaborative working especially where customer interaction has to be prioritized. The agile projects have the ability to reflect, learn and adjust to the project scenarios at a regular interval in order to ensure that the customer is always satisfied and is provided with the outcomes which result in benefits for the client. The agile methods of project management have the ability to integrate planning into the execution which allows a project organization to create a different working mindset which leads to the project team responding effectively to the changing project requirements.

2.4.3 Relevant research in the field of agile project management

Previous research on the agile project management in the field of construction are discussed below as discussed here briefly. The main crux of the research which was carried out in the implementation of scrum in the construction industry deals with the fact that the current process in which the construction projects are being managed needs to be changed effectively which leads to the fact that the stakeholders, materials, competition, and the project user requirements are changing frequently. This has created a gap between the current managerial view on how the construction projects are being conducted and how they can be managed to increase the overall project efficiency. This leads to the fact that new and improved frameworks need to be developed which will help in effective project and product management which can only be done by utilizing the experiences gained from other industries. With this background in mind some construction companies are improving the performance of their project teams which will help to improve their Competitiveness and increases their value addition process.

2.5 Use Of Agile Project Management in Construction

Utilization of agile project management is quickly becoming popular in different industries. This is a management approach which can break the project into the various stages of the project. The agile project management involves the project with a number of different stakeholders which helps improve the construction project at each stage of the project.

2.5.1 How Does Agile Project Management Work in the construction industry?

The key to success in construction projects is continuous collaboration and the adaptation to changing project environment is the key to the project at each stage. The agile project management goes through a number of different stages during the processes of project planning, execution and evaluation which allows for a number of different changes which need to be made throughout the lifetime of construction project.

2.5.2 Core values of agile project management which can be utilized in construction projects.

The core values of agile project management which can be utilized in construction projects are as follows:

- Priority is given to individual project stakeholders and team member interactions over tools and processes.
- Agile project management replaces comprehensive project documentation with working software.
- Agile project management utilizes customer collaborations over the contract negotiations been done in the project.
- Adapting to the project scenario along the way instead of a fixed plan at the start of the project.

2.5.3 Benefits of adopting agile project management in the construction industry

It is the general perception that agile project management cannot be implemented easily on a construction project because the construction industry is expected to be highly irregular and unprofessional but that is not always the case.We can take an example of agile project strategy which allows agile project management to be utilized by utilizing customer and worker input. However, in order to make this project successful the input from customers and project team is to be restricted only to the stages of planning and designing in a construction project. Another major benefit of agile in construction project management software is that it will focus on individual ideas, contributions, and feedback.

2.6 Exploratory Factor Analysis

Exploratory factor analysis (EFA) is a technique which is used commonly in research of preliminary nature. This technique is widely utilized in research topics in which currently not a lot of research is available on the subject topic. Exploratory factor analysis utilizes a large number of variables in research and reduces and summarizes them into a smaller number of variables which can be further represented into different factors and components.

It is a technique which helps us in order to determine whether a number of variables of interest are related to a number of smaller seemingly unknown variables. In order to conduct EFA variables are grouped based on the inter correlations among the set of variables. A common usage of factor analysis is to develop objective instruments for measuring different constructs which are not directly related to each other in real life. EFA technique mainly examines the systematic interdependence among sets of different observed variables. Research on the topic is mainly based on the commonality among the set of variables under observation.

Main purpose of utilizing EFA in research is to summarize the information contained in a large number of variables into a smaller number of factors. Main use case of EFA is to utilize it in exploratory research in which there is little or no knowledge about the information at hand. In order to utilize EFA on attributes of agile project management and CSFs of construction prefabrication effort which were identified using extensive literature review. A questionnaire survey was conducted based on a five-point Likert scale. Results which were obtained using the questionnaire survey were further utilized using the EFA technique. Different terms utilized in the conduct of EFA in research are going to be discussed here one by one in order to provide clarity.

2.6.1 Eigenvalue by Kaiser

Eigenvalue is a factor which represents the total variance which is explained by each factor which is a part of the EFA. For the purposes of conducting a successful EFA we only utilize factors which have an eigenvalue over 1. The main purpose of utilizing EFA is to only retain those factors in our research which accurately elaborate the observed correlation matrix. There are a number of other methods available which can help us in factor retention mainly named parallel analysis and by utilizing visual scree plot analysis.

2.6.2 Kaiser-Meyer-Olkin (KMO) test

The KMO test is utilized in order to know how well suited the research data for the factor analysis technique is. The main purpose of using the KMO test is to measure the adequacy of sampling for each of the variables in the research model. KMO test depicts the proportion of variance among the different variables utilized. Range of values for KMO test ranges between 0 and 1. In order for the KMO test to be deemed adequate for the research at hand the KMO test must return a value greater than 0.6.

2.6.3 Bartlett's test of sphericity

It is a test which is utilized in order to compare the observed correlation matrix to an identity matrix. Main function of this test is to determine whether there is any redundancy between the different variables in the research.

2.6.4 Scree Plot

A scree plot is a graph developed of all the eigenvalues of all the factors which are being utilized in the research. To utilize this test graphical representation of eigenvalues is utilized in order to check for discontinuity or breaks. The screen plot helps us to identify the number of factors which we have to retain during our EFA. In this regard a line graph is developed in scree test which is checked visually for a break point or a change in the slope. The number of data points which lie above the break point is the actual number of factors which must be retained in the analysis. The logic behind the utilization of the scree plot is that it can help us to identify the important factors from the least important factors.

2.6.5 Factor loading

Factor loadings are the output obtained as a result of the application of EFA. They are depicting the correlations between the different observed variables by utilizing a lesser number of factors. In order to be utilized in the EFA a factor loading value greater than 0.6 is suggested suitable for the EFA.

2.6.6 Rotation Method

Results which are obtained after conducting EFA are hard to understand because the principal axis estimation focuses on the computational convenience without taking into account the conceptual clarity. In this regard rotation of factors is designed in order to get a theoretically simpler and easier

to interpret solution by the rotation of axis within the space of the factors in order to bring them closer to the variable of the location. In this regard the orthogonal rotation method of varimax is the most widely used solution. The rotation of matrix helps us to minimize the items which have low loadings and maximizes the items having high loadings in order to provide us with a more simplified and interpretable solution.

CHAPTER 3: RESEARCH METHODOLOGY

The research methodology adopted for this study is divided into four main steps. The first step in the research methodology is to determine the attributes of agile project management. The research method adopted in order to complete this step is to utilize the help of literature review in order to identify the attributes of agile project management. Next step in our methodology is to identify the various critical success factors of construction prefabrication. In order to identify the CSFs of construction prefabrication detailed and extensive literature review was utilized.

3rd step in our methodology is to validate the attributes of agile project management using the EFA analysis. This will help us to reduce the factors which are being identified using the literature review and help us to identify the attributes of agile project management which are contributing the most to success of construction prefabrication effort. Table 3.1 contains all the different objectives which are obtained from the research in question. It also enlists the research methods utilized as well the outcomes which was obtained as a result of the application of these research method. A detailed analysis of the table 3.1 attached below leads to a much better understanding of the research in question and how we can effectively understand it.

Table 3.1 Presents the research methodology for research.

Processes & Objectives	**Research Methods**	**Outcomes**
Determine the attributes of agile project management.	Literature review.	Validation of Attributes through extensive literature review.
Determine the critical success factors of construction prefabrication.	Literature review.	Validation of critical success factors of construction prefabrication through extensive literature review.
Analysis of attributes of agile project management.	Analysis through application of	Grouping of attributes of agile project management which can then be applied to construction prefabrication projects.

	exploratory factor analysis.	

3.1 Research Problem

In the past works examined, there have been a number of different research which are done in order to implement agile project management in different fields and industries. This trend is being spearheaded by the implementation of agile project management in the technology sector. Overtime researchers have used the success shown by the implementation of agile project management in the technology sector to look for ways this innovative project management technique can be implemented in the construction industry.

In this regard the shortcomings of the use of traditional project management approach are expected to be overcome with the implementation of agile project management technique in favor of traditional project management approach. Same is the case with the implementation of construction prefabrication instead of the traditional construction approach. A number of research is available on this topic as well. There is no explicit research on the implementation of agile project management in construction prefabrication. Research is available on scrum is implementation in the construction design phase which can be used as a basis for implementation of agile project management in construction prefabrication.

3.2 Attributes of Agile Project Management

Extensive literature review was conducted in order to determine the attributes of agile project management which could be beneficial to achieve the critical success factors of construction prefabrication. Table 3.2 refers to all the attributes of agile project management identified as a result of detailed literature review conducted in this regard.

Table 3.2 Attributes of agile project management.

Attributes of Agile Project Management	
A1	Regular sprints (Iterations)
A2	Value-driven development
A3	Continuous (adaptive) planning
A4	Multi-level planning in agile development
A5	Relative estimation
A6	Emergent feature discovery
A7	Continuous testing
A8	Continuous improvement
A9	Small, cross-functional teams
A10	Reduction in waste
A11	Strict production plan and process
A12	Production process design optimization
A13	Cost Effective
A14	Proactive Adaptation

A15	Adaptive project management
A16	Increased labor productivity
A17	Reduction in labor cost
A18	Sustainable development
A19	Stakeholder engagement
A20	Transparency
A21	Essential Reliability
A22	Responsiveness

3.3 Critical Success Factors of Construction Prefabrication

After extensive literature review critical success factors of construction prefabrication are detailed in table 3.3:

Table 3.3 Critical success factors of construction prefabrication projects.

Success factors of prefabrication in construction industry	
S1	Standardization
S2	Mass production
S3	Economics of scale

S4	Reduction in construction costs
S5	Environmentally friendly
S6	Steady supply of materials
S7	Offsite construction
S8	Reduction in risks associated with construction
S9	Energy efficient
S10	Enhanced site safety
S11	Collaboration
S12	Flexible
S13	High Production efficiency
S14	Human machine interaction
S15	Parallel development of design and fabrication
S16	Fast paced development
S17	Reduction in construction time
S18	Sustainability
S19	Reduced need for skilled labor on construction site
S20	Reduced construction wastes
S21	Reduced carbon emissions

S22	Improved Quality
S23	Improved Productivity
S24	Recycling of construction wastes
S25	Reduction in complexity of task
S26	Repetitive Design
S27	Effective Stakeholder management

3.4 Questionnaire Survey

Questionnaire survey to be conducted in order to validate the attributes of agile project management and critical success factors of construction prefabrication. Professionals were asked to rank these factors as per their importance on the 5-point Likert Scale. Responses were collected primarily through construction professionals.

3.4.1 Cronbach's Alpha

Cronbach's alpha is a measure of the reliability or internal consistency of test items. Calculation of Cronbach's Alpha was carried out for the questionnaire and value was determined. A value of 0.9 and above is significant of a internally consistent set of test items. In the application of technique of EFA Cronbach's Alpha is calculated in order to ensure that the data set is internally consistent.

3.4.2 Relative Index of Importance

The relative index of importance (RII) is a regression-based index. RII is useful because it considers the size of the population and the relative disadvantage experienced by different groups. Similarly a higher value of RII is considered to be highly significant and any variable having a high value of RII is considered relatively more important as compared to the rest of the variables. RII test was applied to responses and a relative index was generated for all factors.

3.5 Exploratory Factor Analysis

Implementation of exploratory factor analysis (EFA) was made on the basis of responses gathered against attributes of agile project management. The analysis of results of questionnaire survey was necessary in order to group the attributes of agile project management into sets which are distinguishable from each other. Before the successful implementation of exploratory factor analysis.

Once the questionnaire survey results were analyzed under EFA a total of 11 attributes of agile project management were grouped into two groups. Exploratory factor analysis (EFA) was implemented on the responses gathered against each csfs. The figures below show the scree plot generated which shows the total number of groups to be maintained to be 2. In the table 3.4 it can be seen that the total variance of the attributes of agile project management is indicative of a total of 2 groups for further analysis. In Figure 3.1 we can see the scree plot for the research in question. If we have a closer on the figure we see that a total of 2 component numbers are retained in result of application of EFA.

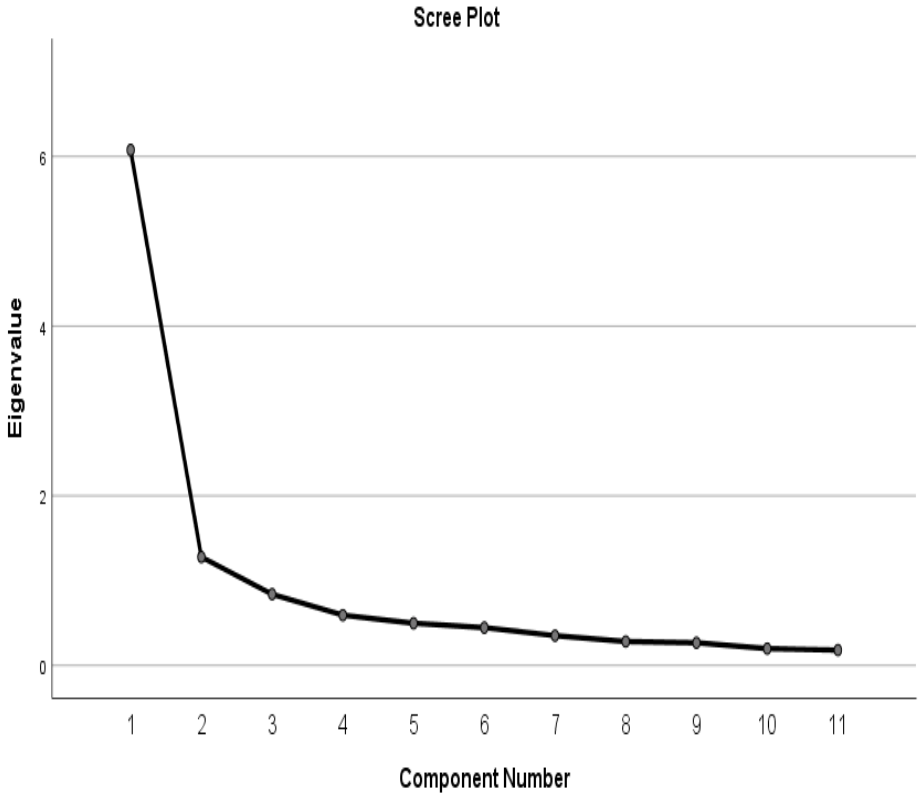

Figure 3.1 Scree plot for attributes of agile project management.

Table 3.4 The total variance explained for attributes of agile project management.

Total Variance Explained									
	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% Of Variance	Cumulative %	Total	% Of Variance	Cumulative %	Total	% Of Variance	Cumulative %
1	6.076	55.234	55.234	6.076	55.234	55.234	4.552	41.384	41.384

2	1.278	11.614	66.848	1.278	11.614	66.848	2.801	25.464	66.848
3	.839	7.628	74.475						
4	.592	5.380	79.855						
5	.496	4.511	84.366						
6	.445	4.044	88.410						
7	.351	3.188	91.599						
8	.281	2.552	94.151						
9	.266	2.419	96.569						
10	.197	1.793	98.362						
11	.180	1.638	100.000						
Extraction Method: Principal Component Analysis.									

CHAPTER 4: RESULTS AND ANALYSIS

This chapter reflects on the results and analysis which were obtained as a result of the research conducted. Results obtained as a result of the questionnaire survey conducted are discussed here in detail. Discussion is done on the results obtained from application of technique of EFA. In the later parts of this chapter discussion is done on the further recommendations made as a result of this research as well as the limitations of the research conducted.

4.1 QUESTIONNAIRE SURVEY

In order to take feedback from industry experts and professionals a detailed questionnaire survey was conducted in order to better understand the point of view of industry professionals on the application of agile project management on the construction prefabrication effort. A total of 102 responses were generated because of this. The demographics of the survey in question are detailed here.

4.1.1 Professional experience

It was important to establish the overall professional experience of the construction industry professional to develop a better understanding of the demographics of the survey conducted. In this regard a total of 102 responses were received for this survey field alone. Out of these the most common response (31.4%) of the respondents had an overall construction industry experience of 3-5 years. 2nd most common response (22.5%) of the respondents had a total industry experience of 5-10 years in total. A total of 19.6% of the respondents had an overall construction industry experience of 1-2 years between them. The 4th largest response group had an overall construction industry experience of 19.6%. The lowest response rate of 2.9% was achieved from the construction industry professionals having construction industry experience of above 25 years in

total between them. A pie chart is detailed in figure 4.1 which helps us better understand the overall demographic of the experience of industry professionals in regard to the responses received.

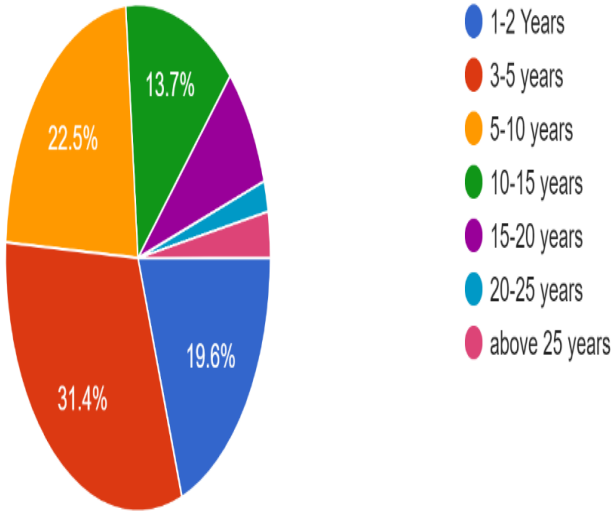

Figure 4.1: The professional experience of the participants in the survey

4.1.2 Experience in construction prefabrication projects

The next most important question which was asked by the recipients of the questionnaire was how much experience they had in the construction prefabrication process. In this regard it was established that a total of 41.2% of the respondents had no experience in any construction prefabrication project whatsoever. 2nd most common response 30.4%) of the recipients had an overall experience of 1-2 years in construction prefabrication projects. 3rd most common response (9.8%) of the recipients in total had an experience of 3-5 years in total in the field of construction prefabrication projects. 4th most common response (8.8%) of the recipients had a construction

prefabrication projects experience of 5-10 years between them. Figure 4.2 details the experience of participants in the construction prefabrication projects.

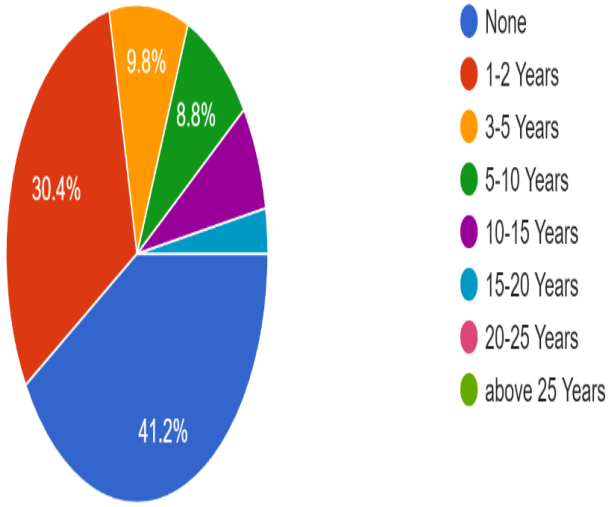

Figure 4.2: The experience of participants of research in construction prefabrication projects

4.1.3 Type of organization

Another important demographic of the survey questionnaire was to establish the type of organization that the construction industry professionals were working in. In this regard an overwhelming majority of the recipients were working on the contractor side of the construction projects (52.5%). The next most common type of organization type was the client to which a total of 28.7% of the recipients belonged to the contractor type of organization in the construction industry. Only 18.8% of the recipients belonged to the consultant type of organization in the construction industry. Figure 4.3 details the type of organization the participants of the survey belong to. 6

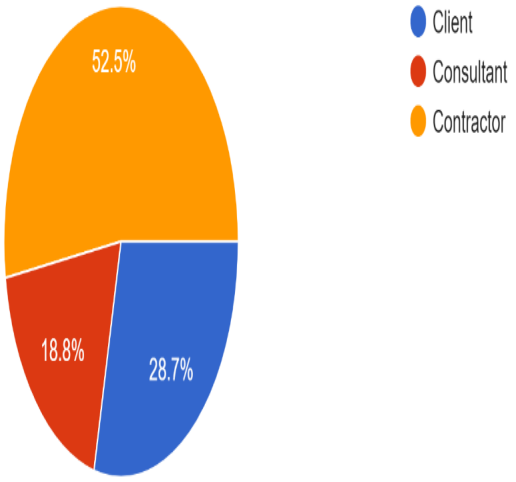

Figure 4.3: The type of organization to which the participants of the survey belong to

4.2 Statistical Tests on Survey

In order to better understand the results obtained from the conduct of questionnaire survey a number of statistical techniques were applied which are named here below:

- Kaiser-Meyer-Olkin (KMO)
- K1-Kaiser's Eigenvalue>1
- Scree Test

4.2.1 Kaiser-Meyer-Olkin (KMO) and Bartlett's test

Some tests are performed to check the internal consistency and adequacy of the sample which is going to be utilized in order to be used for EFA. The application of KMO and bartlett's test serves to purpose to determine how tightly correlated any variable is with other variables in the EFA correlation matrix. In this regard data is significant for factor analysis if it has a significant value of loss than 0.05. It also has to show that the matrix developed is not an identity matrix. Once we

have developed that the data being used is appropriate for factor analysis only then we can move to the actual factor analysis calculation. For the purpose of research, the value for significance was established to be below 0.05 and the data was deemed significant for application of factor analysis technique. The table 4.1 shows the results of KMO and Bartlett's test.

Table 4.1: Results of KMO and Bartlett's test.

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.898
Bartlett's Test of Sphericity	Approx. Chi-Square	689.125
	Df	55
	Sig.	.000

4.2.2 K1-Kaiser's Eigenvalue>1

Kaiser's eigenvalue represents the total variance which is detailed by each factor in the factor analysis technique. Only the factors which had an eigenvalue of greater than 1 were retained for the factor analysis as this is the common practice as well. The reason behind doing this is to only produce the factors which are effectively depicting the observed correlation matrix.

4.2.3 Scree Test

The scree test is used as the visual representation of the eigenvalues, and it is used to determine the breaks between the plots. Scree plot is the most commonly used technique in order to determine

how many factors should be retained in order to be utilized in factor analysis. Only the actual number of data points which are above the break (Not including the datapoints which are in the break itself) is the actual number of factors which are needed to be obtained as a result of factor analysis. The main reason for the utilization of the scree plot is to separate the major factors from the trivial factors. The screen plot developed clearly shows that the total number of factors to be retained is 2 and the rest of the factors need to be rejected. Figure 4.4 shows the results of scree test.

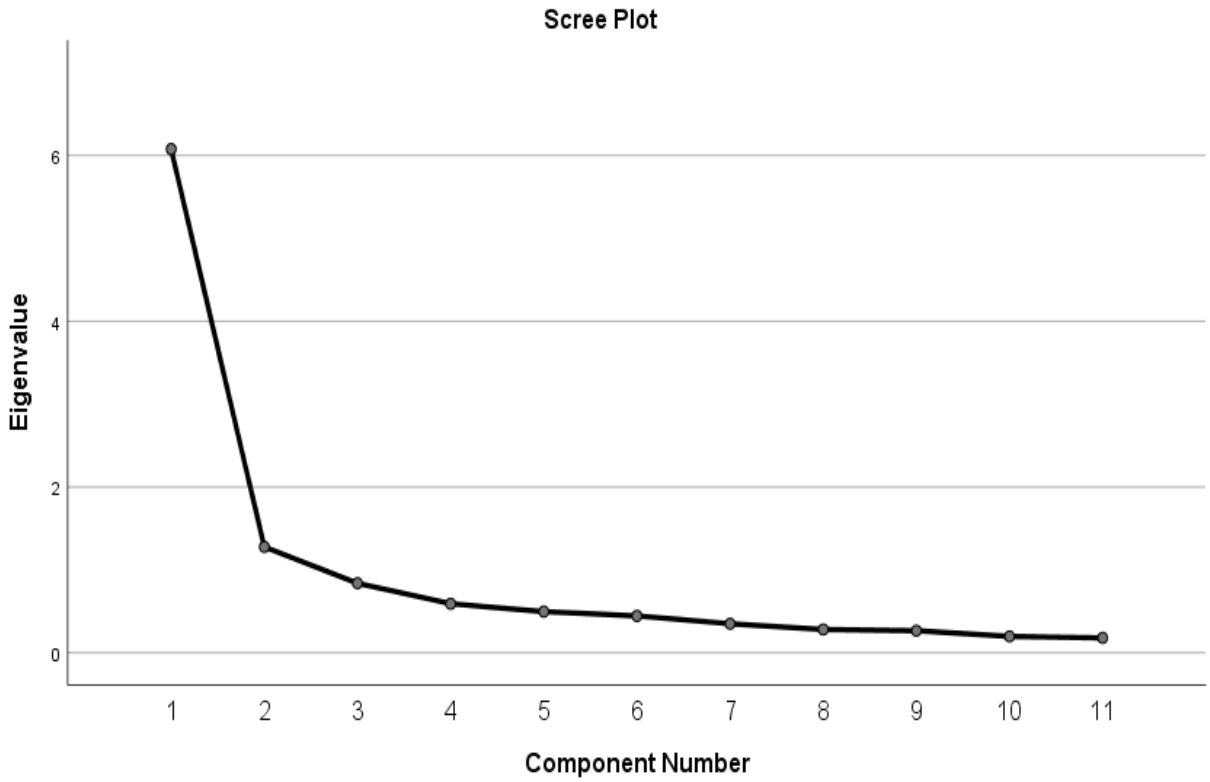

Figure 4.4: The results of scree plot.

4.3 Factor Loading and Rotation Method

Factor loadings are used to depict the correlation between the different observed variables by utilizing a smaller number of variables. To be deemed useful factor loadings must be greater in

value than 0.6. There are two types of rotation techniques commonly in use. One of these is orthogonal rotation and the other one is oblique rotation. For the purpose of this research orthogonal rotation technique was utilized because output of orthogonal rotation factors provides us with uncorrelated factors.

Initially it gets hard to depict the results because the principal axis has a focus on computational convenience without considering the conceptual clarity between the variables. In this regard rotation of factors is designed in order to get a simpler solution. Among the different types of techniques available for factor rotation the most commonly used method in SPSS is the varimax rotation method.

After applying the varimax technique for factor rotation we will be able to minimize factors with low item loading and maximize the results for factors with high item loading. Varimax rotation technique also allows us to avoid the issue of cross loading. This issue occurs when one factor shows a high correlation with two different factors. To avoid this issue varimax was applied after excluding the factors showing factor loadings less than 0.6.The rotated component matrix thus received after applying the varimax rotation method is provided in table 4.2.

Table 4.2: The rotated component matrix.

Rotated Component Matrix		
	Component	
	1	2
[Regular sprints (Iterations)]		.879
[Value-driven development]		.852
[Continuous (adaptive) planning]		.739

[Multi-level planning in agile development]	.546	
[Continuous testing]	.683	
[Continuous improvement]	.817	
[Reduction in waste]	.775	
[Strict production plan and process]	.775	
[Cost Effective]	.695	
[Proactive Adaptation]	.795	
[Stakeholder engagement]	.787	
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.		
a. Rotation converged in 3 iterations.		

CHAPTER 5: CONCLUSIONS

5.1 Review of Study

The contents of this research were primarily divided into two main parts. The first part of the research primarily consists of a literature review which investigated two main parts. One of them being attributes of agile project management which can be effectively utilized in order to augment the construction prefabrication effort. Next one being the literature review on critical success factors of construction prefabrication which we aspire to achieve in order to make a construction prefabrication project successful. The Attributes of agile project management were then scrutinized in order to further reduce based on their frequency in literature review. After the reduction of attributes of agile project management, a questionnaire survey was conducted in order to validate the attributes of agile project management.

In the second part of this research the statistical technique of EFA was applied to the attributes of agile project management in order to further identify the underlying variables between the different attributes of agile project management. After the statistical technique of EFA was applied to the research two different groups of attributes of agile project management were developed which can help us in augmenting our overall construction prefabrication effort.

5.2 Research Findings

The main findings that the research in question was able to identify are as follows:

- The construction industry is currently focused primarily on the traditional project management methodology and currently more advanced project management methods like agile project management are not applied extensively to construction projects.

- Construction prefabrication is deemed very important for the construction industry in the days to come by construction experts and has vast applications in the construction industry of the future.
- A number of attributes of agile project management can be applied to construction projects, especially in the construction prefabrication projects and can result in a number of benefits for the stakeholders.
- A number of research is available on the topic of application of agile project management in construction projects but so far implementation of agile project management in construction prefabrication projects has not been discussed extensively.

5.3 Limitations

The research in question aspired to implement agile project management in the field of construction prefabrication but due to certain limitations this could not be done. But the research in question can act as a steppingstone and can lead to further research in the area under discussion. Further research can also be done on the topic regarding the implementation of different attributes of agile project management in the different construction prefabrication projects in order to better understand the application of agile project management in the field of construction.

Implementation of agile project management in other project areas like procurement, R&D and safety can also be done in future research.

This research can act as a way forward for further research in the knowledge area discussed here. Currently agile project management is being applied to a number of fields all over the world. Currently there is very little application of agile project management in the construction field.

It is expected that in the coming days researchers will focus on the further development of research in the field of application of agile project management in the construction industry.

Another aspect of this research is that keeping in mind that the field of construction prefabrication is relatively new as well. Use of agile project management like innovation can lead to the promotion of construction prefabrication as an alternative to traditional project delivery approaches.

REFERENCES

LJ Magill, N Jafarifar, A Watson. "4D BIM integrated construction supply chain logistics to optimise on-site production.", 2020.

A Fitriawijaya, T Hsin-Hsuan. "A approach to supply chain management in a BIM-enabled environment." 2019.

Abbas Elmualim, Sherif Mostafa, Nicholas Chileshe, Raufdeen Rameezdeen,. "Unmaking Waste in Production and Consumption towards the circular economy ." Emerald Insight, 2018.

Albuquerque, Felipe. "Lean product development and agile project management in the construction industry ." Emerald Insight , 2019.

Alvarez1, Hans Jakob Wagner1 · Martin. "Towards digital automation fexibility in large-scale tim ber construction: integrative robotic prefabrication and co-design of the BUGA Wood Pavilion." Construction Robotics, 2020.

Amos Darko, Albert Ping Chuen Chan, Ernest Effah Ameyaw, Emmanuel. "Review of application of analytic hierarchy process (AHP) In construction ." International Journal of Construction Management, 2018.

Anand Jose Paul, Sherin K Rahman. "STUDY ON AGILE MANAGEMENT IN CONSTRUCTION PROJECT USING SCRUMBAN TECHNOLOGY ." International Research Journal of Engineering and Technology (IRJET) 5, no. 11 (2018).

Braimah, N. "Understanding construction delay analysis and the role of pre-construction programming." 2014.

CZ Li, RY Zhong, F Xue, G Xu, K Chen. "Integrating RFID and BIM technologies for mitigating risks and improving schedule performance of prefabricated house construction." 2017.

David Leicht , Daniel Castro-Fresno , Joaquìn Dìaz and Christian Baier . "Multidimensional Construction Planning and agile organized project execution-The 5D Prompt method." Sustainability , 2020.

David Leicht, Daniel Castro-Fresno. "Multidimensional Construction Planning and Agile Organized Project Execution—The 5D-Prompt Method." Sustainability, 2020.

F Shadram, TD Johansson, W Lu, J Schade. "An integrated BIM-based framework for minimizing embodied energy during building design." 2016.

FST Hewavitharana, A Perera. "Sustainability via ERP and BIM Integration." 2018.

Hai-Min Lyu, Ph.D., S.M.ASCE1. "Risk Assessment Using a New Consulting Process in Fuzzy AHP ." ASCE , 2019.

Hidalgo, Enric Senabre. "Adapting the scrum framework for agile project management in science: Case study of a distributed research initiative ." Heliyon, 2019.

Howell, G.A., G. Ballard, and Tommelein. "Construction engineering-reinvigorating the discipline." 2011.

J Zhang, H Li, H Golizadeh, C Zhao, S Lyu. "Reliability evaluation index for the integrated supply chain utilising BIM and lean approaches." 2020.

Jahangiri, Katayoun. "Site selection criteria for temporary sheltering in urban environment." International Journal of Disaster Resilience in the built, 2020.

Jingke Hong, Geoffrey Qiping Shen, Zhengdao Li, Boyu Zhang, Wanqiu Zhang. "Barriers to Promoting Prefabricated Construction in China: A Cost–Benefit Analysis." Journal of cleaner production , 2017.

Julia-Anne Scholz, Felix Sieckmann, Holger Kohl. "Implementation with agile project management approaches: Case Study of an Industrie 4.0 Learning Factory in China." 2020.

Kamaruzzamana, Syahrul Nizam. "Developing weighting system for refurbishment building assessment scheme in Malaysia through analytic hierarchy process (AHP) approach." Energy Policy , 2018.

Lang, Jason H. Sharp and Guido. "Agile in Teaching and Learning: Conceptual Framework and Research Agenda." Journal of Information Systems Education 29, no. 2 (2018).

Leslie J. Magill, Naeimeh Jafarifar, Alan Watson & Temitope Omotayo. "4D BIM integrated construction supply chain logistics to optimize on-site production ." International Journal for Construction Management, 2020.

Lia, Xiao. "Integrating Building Information Modeling and Prefabrication Housing Production." Automation in construction , 2019.

M Wang, SJ Ahn, Y Zhang. "Automatic material estimation by translating BIM data into ERP readable data for panelized residential construction." 2019.

Montasser Hamida, "BIM semantics for digital fabrication: A knowledge-based approach." Automation in Construction, 2018.

NČ Babič, P Podbreznik, D Rebolj. "Integrating resource production and construction using BIM." 2010.

Niu1, Sanyuan. "Logistics Planning and Visualization of Modular Integrated Construction Projects Based on BIM-GIS Integration and Vehicle Routing Algorithm." Modular and Offsite Construction, 2019.

Papadonikolaki, E. "Alignment of Partnering with Construction IT: Exploration and Synthesis of network strategies to integrate BIM-enabled Supply Chains." 2016.

Papadonikolaki, E. "The digital supply chain: mobilising supply chain management philosophy to reconceptualise digital technologies and building information modelling (BIM)." 2020.

PL Le, A Chaabane, TM Dao. "BIM contributions to construction supply chain management trends: an exploratory study in Canada." 2019.

R Eadie, M Browne, H Odeyinka. "A survey of current status of and perceived changes required for BIM adoption in the UK." 2015.

S Ghosh, S Negahban, YH Kwak. "Impact of sustainability on integration and interoperability between BIM and ERP-A governance framework." 2011.

S Oberoi, D Holzer. "Mechanical contractors: the key for supply chain integration in lifecycle BIM." 2016.

Sevilay Demirkesen a, Beliz Ozorhon. "Impact of integration management on construction project management performance ." International journal of project management, 2017.

Shen, Ibrahim Yahaya Wuni and Geoffrey Qiping. "Critical success factors for management of the early stages of prefabricated prefinished volumetric construction project life cycle." Emerald Insight , 2020.

Sherif Mostafa, Ki Pyung Kim, Vivian W. Y. Tam & Payam Rahnamayiezekavat. "Exploring the status, benefits, barriers and opportunities of using BIM for advancing prefabrication practice." Internation Journal of Construction Management, 2018.

Sherif Mostafa, Ki Pyung Kim, Vivian W. Y. Tam & Payam Rahnamayiezekavat. "Exploring the status, benefits, barriers and opportunitites for using BIM for advancing prefabriation practice ." International Journal of Construction Management, 2018.

Tan Tan, Ke Chen, Fan Xue, Weisheng Lu. "Barriers to Building Information Modeling (BIM) implementation in China's." Journal of Cleaner Production, 2019.

Tan Tan, Ke Chen, Fan Xue, Weisheng Lu. "Barriers to Building Information Modeling (BIM) implementation in China's prefabricated construction: An interpretive structural modeling (ISM) approach." Journal of Cleaner Production, 2019.

V Getuli, SM Ventura, P Capone, ALC Ciribin. "A BIM-based construction supply chain framework for monitoring progress and coordination of site activities." 2016.

William Ho, Xin Ma. "The state-of-the-art integrations and applications of the analytic hierarchy process." European Journal of Operational Research , 2017.

Yan Li, Yanfang Gu, Chunlu Liu. "Prioritising performance indicators for sustainable construction and development of university campuses using an integrated assessment approach." Journal of cleaner production , 2018.

Yang Liu, Jianjun Dong and Ling Shen. "A Conceptual Development Framework for Prefabricated Construction Supply Chain Management: An Integrated Overview." Sustainability , 2020.

Yasaman Arefazar, Ahad Nazari, Mohammad Reza Hafezi & Sayyed Amir. "Prioritizing agile project management strategies as a change management tool in construction projects ." International Journal of Construction Management, 2019.

YR Chen, HP Tserng. "An integrated methodology for construction BIM & ERP by using UML tool." 2017.

Zhou, Jingyang. "A selection model based on SWOT analysis for determining a suitable strategy of prefabrication implementation in rural areas." Sustainable cities and societies , 2019.

Hai-Min Lyu, Wen-Juan Sun, Shui-Long Shen and An-Nan Zhou, “Risk Assessment Using a New Consulting Process in Fuzzy AHP." American Society of Civil Engineers,2014.

William Ho and Xin Ma. "The state-of-the-art integrations and applications of the analytic hierarchy process." Department of Management and Marketing, The University of Melbourne,2017

Amos Darko, Albert Ping Chuen Chan, Ernest Effah Ameyaw, Emmanuel Kingsford Owusu, Erika Pärn & David John Edwards. "Review of application of analytic hierarchy process" International Journal of Construction Management, 2017

Katayoun Jahangiri, Hasti Borgheipour, Saeid Bahramzadeh GendeshminSite, Amirhossein Matin Ghazaleh, and Monazami Tehraniselection, “criteria for temporary sheltering in urban environment Resilience in the Built Environment." Vol. 11 No. 1, 2020

Syahrul Nizam Kamaruzzamana, Eric Choen Weng Loub, Phui Fung Wongc, Ruth Woode, Adi Irfan Che-Anid. "Developing weighting system for refurbishment building assessment scheme in Malaysia through analytic hierarchy process (AHP) approach." Energy Policy, 2018.

Yan Li, Yanfang G, u, Chunlu Liu."Prioritising performance indicators for sustainable construction and development of university campuses using an integrated assessment. approach Journal of Cleaner Production." 2018.