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The Future of Construction: Investigating the Latest Trends & Innovations in Off-Site Construction Solutions for Worker Safety in the United Arab Emirates

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Abstract: - One of the riskiest industries for workers is construction, which has the highest death rate when compared to other industries. With the potential for falls, being struck by things, electrocution, and getting trapped between objects, safety is a major issue for those working in the construction business. Therefore, improving workers safety in controlled environments is a fundamental requirement within the construction industry that is growing in the United Arab Emirates. Although prefabrication and modular construction are now continuing to have increasing trends in the construction industry and have a significant response to increasing the efficiency, nevertheless, it is feared that this new construction approach would bring new threats to worker's safety or can have its positive effect on safety. Accordingly, this research aims to evaluate the influence introduced by the new prefabrication technology on workers safety within construction sites. A questionnaire was used to gather data from the relevant parties, which included project managers, project engineers, safety engineers, site engineers and workers. The questionnaire was divided into three primary sections: Training & Education, Safety Compliance, and Incident Rates. 106 participants from various construction companies in the United Arab Emirates provided the pertinent data, which was then analyzed using three-way ANOVA (Analysis of Variance) technique to examine the relationship between the three mentioned variables. The gained results showed that the Incident Rates, Safety Compliance, Training & Education were all statistically significant. The interaction between all three variables showed no combined effect on the safety score.

Keywords: Construction management, prefabricated construction, risk management, safety compliance, worker safety

I. INTRODUCTION

The construction industry is one of the most dangerous for workers, having the highest number of deaths than other industries, and for this reason, construction safety has alwaysbeen the first priority for any contractor on all job sites (JOHNSON, 2019).

In recent years, there has been an accelerated shift towardsthe use of prefabrication in new construction.

Prefabrication is the assembly of parts that are manufactured off-site in a factory and then transported to their final assembly or destination. Furthermore, the process involves three stages which are production, transportation, andassembly. On the other hand, modularisation is the process bycreating structures which can be broken up into separate parts for an easier assembly and transportation (Bagatsing, 2023). Understanding the many benefits and limitations of theoff-site construction solutions can help the industry professionals as well as homeowners and consumers to make more informed decisions regarding the construction, design, management of buildings, and increase workers safety.

The thesis will investigate the difference in construction methods, both Prefabricated approach and Traditional Construction to see which one has a higher impact towards worker safety. The thesis will also focus on optimizing the assembly process, a critical aspect of modern construction. The assembly phase also brings unique difficulties and risks that call for careful attention. This choice is essential as it will ensure smooth coordination and lower the possibilities of mistakes or injuries.

The United Arab Emirates (UAE) had been increasingly adopting prefabrication and modularization for construction projects, such factors include:

Efficiency & Speed: Given the rapid pace of development inthe UAE, accelerating construction projects through prefabrication is a priority.

Government Initiatives: Prefabrication and other contemporary building methods are supported by the UAE

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government, which has been encouraging innovation in infrastructure development and construction.

Technological Advancements - Prefabricated and modular pieces in construction projects are becoming easier to design and coordinate because of the widespread use of modern technologies like Building Information Modeling (BIM).

The construction industry is constantly evolving and as it moves forward into the future, it is important to stay up to date on the innovations and latest trends in construction(Bagatsing, 2023)

II. LITERATURE REVIEW

A. The Prefabrication Process

Prefabrication refers to the method or practice of assembling components of structures or buildings at a location different from the construction site such as a factory or any other manufacturing site. Moreover, the process involves transporting either sub-assemblies or complete assemblies to the construction site (Gausch & Guevara, 2022).

B. The Growth of The Prefabricated Approach in The UnitedArab Emirates

The growing adoption of advanced construction methods to reduce the rising number of unskilled labors and the time represents one of the key factors which can positively influence the sales of prefabricated building components in the United Arab Emirates (UAE) (Imarc, 2021).

Furthermore, the usage of Prefabricated off-site solutions helps in decreasing construction debris and pollutants and minimizing the overall cost of the project as well as human errors. Prefabricated Buildings components are manufactured using advanced technologies with controlled quality specifications which can extend the average lifespan of buildings in the UAE (Imarc, 2021). Moreover, IMARCGroup expects the prefabricated market will grow by 7% within the year 2021-2026 (Imarc, 2021).

These benefits along with the increasing preferences of contractors for off-site construction are strengthening the growth of the market in the country (Imarc, 2021). Moreover, the UAE Government began numerous development programs which are a long-term plan for the economic development of the emirate.

C. Benefits of Prefabrication for the Safety of Workers Prefabrication has been acclaimed for a variety of benefits such as cost savings, time savings, better site security, higher quality, and improvement for site safety. Moreover, there areseveral benefits of applying prefabrication into theconstruction industry.

Controlled Environment: Prefabrication can put workers into a controlled environment where many risks of the traditional construction sites can be avoided. For example, offsite construction eliminates risks from weather conditions in which there are no slippery surfaces from rain that helps in cutting down slips and falls and avoiding risk of electrocutionto exposed electrical lines resulting from moisture (JOHNSON, 2019).

Less On-Site Workers: Less workers onsite means less workers who can potentially be killed, injured, or involved in any safety accident. Furthermore, the workers that install the prefabricated pieces are more experienced allowing sites to leverage the expertise of workers knowledge while minimizing the need for the less trained workers in proper safety procedures (JOHNSON, 2019). Moreover, a less workers onsite results in a less crowded jobsite which can lead to lessen the potential of workers to run into issues due toa crowded working environment or lack of space.

Safer Scheduling: Offsite construction can help in safer installation practices and better planned schedules for installations which can help in minimizing the need for rushed work or jammed spaces (JOHNSON, 2019).

Less Waste and Clutter: Offsite construction enables a better material flow where less materials that are stored on-site can reduce debris and clutter to achieve a more organized, cleaner, and safer project site (JOHNSON, 2019).

Minimize Risky Site Elements & Heights – Since falls are thenumber one killer of the Fatal Four, maximizing the

work done at the ground level can have a vast impact (JOHNSON, 2019). Furthermore, with off-site construction, permanent scaffolding is used, which presents less opportunities for error than the frequently assembled and reassembled scaffolding which is used on traditional sites.

*D. Traditional Construction Versus Prefabricated Approach*Over the years, the building sector has undergone substantial change, with two main approaches that stand out: traditional construction and the prefabricated approach. In the building industry, worker safety is of utmost importance and plays a major role in determining whether to use prefabricated materials or traditional construction techniques. We will look at how each strategy affects worker safety in this introduction, as well as the steps taken to guarantee the safety and welfare of construction workers.

1. Traditional Construction & Worker Safety

Traditional Construction & Worker Safety has a long history and well-established procedures; thus, it prioritizes worker safety, but it also presents a unique set of safety risks:

On-Site Hazards: Traditional construction sites expose workers to a variety of risks associated with their employment, such as the possibility of falls, accidents involving heavy machinery, and exposure to inclement weather.

Scaffolding and Heights: Workers in traditional construction frequently perform work at heights that need the use of scaffolding, ladders, and other equipment, all of which raise the possibility of accidents.

Safety Protocols: Rules and procedures pertaining to safety, such as personal protective equipment (PPE), are essential tomitigate on-site risks in traditional construction.

Skilled Labor: The need for skilled labor in traditional construction means that in addition to the general safety precautions, personnel need to receive intensive training in safety procedures and practices.

2. Prefabricated Approach & Worker Safety

Prefabricated Approach & Worker Safety prioritizes workersafety and offers unique advantages in this regard.

Controlled Environment: Prefabrication occurs in acontrolled factory environment, minimizing potential safety dangers and limiting exposure to external variables, such as harsh weather.

Efficient Assembly: Prefabricated components are made to assemble quickly and safely on the job site, reducing the needfor labor-intensive and dangerous construction work.

Worker Training: Prefabrication workers can need specific industrial work training that focuses on safe machine operation and assembly procedures.

Reduced On-Site Risks: There can be a significant reduction in the number of laborers on-site and the related dangers when a large percentage of the construction is done off-site.

Precision and Quality Control: Precision and strict quality control are made possible by prefabrication, which producesbuilding components that are safer and more dependable.

E. Construction Safety Study in the UAE

This section will focus on the identification of factors influencing safety in prefabrication technology, and the confirmation of the research methodology.

This study was necessary because there were very few studies about the safety performance of the UAE's construction industry and none about the Emirate of Dubai up to that point. A study under the title “Health & Safety Influence on the Construction Project Performance in United Arab Emirates (UAE)” has been conducted with a total of 130 companies participating. Furthermore, the study showcased the following in UAE’s construction companies:

71% have no training of workers (Shibani, Saidani, & Alhajeri, 2013).86% of respondents admitted that they did

not adhere to reporting accidents procedures (Shibani, Saidani, & Alhajeri, 2013).69% have a serious lack of understanding of the importance of Health & Safety policy importance (Shibani, Saidani, & Alhajeri, 2013).

F. Prefabricated Construction as a tool for Good Mental Health

The prefabrication approach can deliver a quality of projects in a shorter time while increasing the productivity which can positively impact the mental health of workers by potentially weakening the impacts of industry-related stressors that causes other stressors (Fagberno, Sunindijo, Illankoon, & Frimpong, 2023).

Safety risks are easier to identify at an early stage of prefabricated construction and can facilitate a safer construction than the traditional approach.

Through the reduction in on-site overlap, project duration andunambiguous design, and construction information, workpressure and all the other associated work-related stressors such as long working hours, work overload and unsafe workspeed could be reduced.

Moreover, to a better psychological work environment, prefabricated construction also enhances a cleaner construction with the ease of housekeeping due to the disaggregation of tasks through standardization which ensures that workers carry out their duties in a good physical work environment and reduces the chances of safety incidents (Fagberno, Sunindijo, Illankoon, & Frimpong, 2023)

1. Industry Related Stressors

Industry Related Stressors dictate the level of physical, technological, mental, and other requirements of workers to fulfill their workplace obligations. Furthermore, excessive work pressure can lead to work overload which is a functionof heterogeneity of every project in the industry.

The technical instructions in the construction industry are continually amended to suit every project with an increased opportunity of experiencing ambiguity in work-related instructions and procedures. Moreover, other implications oftime pressure on construction workers are long working hours which can play a major role in the poor work-life balance of construction workers (Fagberno, Sunindijo, Illankoon, & Frimpong, 2023).

2. Management and Organizational Stressors

Management and Organizational Stressors come from management responses and impacts from the industry relatedstressors. Furthermore, interpersonal conflicts for example can arise from improper communication from new and ever-changing ideas and instructions.

3. Personal Stressors

Personal Stressors can be grouped under the personal classification such as marital status, gender discrimination, age discrimination, gender discrimination, harassment, and financial difficulties which results in low socioeconomic status among construction workers.

The construction workplace attracts workers from all over the world with different backgrounds and this has promotedculturally motivated barriers such as cultural conflicts, language barriers and racial discriminations.

G. Assembly Stage in Prefabrication

Prefabrication, a method of building that involves producing building components off-site before they are installed on the construction site, has many benefits, including lower costs, better quality control, and quicker project completion.

The assembly of these pre-made components at the construction site is a crucial step in the prefabrication process. While prefabrication can increase the efficiency and security of construction, the assembly phase also brings unique difficulties and risks that call for careful attention.

Prefabrication's assembly phase entails inherent hazards because of the nature of the work required and the difficulty in coordinating numerous components. The following are some of the main reasons why prefabrication

assembly can berisky:

Handling Heavy Components: Prefabricated components canbe heavy and unwieldy, including concrete panels, steel frames, or modular pieces. Workers may experience strain because of lifting, placing, and aligning these components, which raises the possibility of musculoskeletal injury.

Work at Heights: For a structure to be stable, prefabricated components must be connected, fastened, and aligned correctly. Safety risks might result from assembly mistakes or inadequacies that affect the building's structural integrity. Equipment Hazards: When heavy machinery, such as cranes and forklifts, is used during assembly, there is a risk of accidents caused by the equipment if it is not operated by trained workers or if it malfunctions.

1.What Could Go Wrong?

As prefabrication becomes more popular in the construction sector, it is important to distinguish between its various uses and forms and investigate the effects on worker welfare to avoid hidden dangers becoming a statistic (Franks, 2018). Off-site methods and processes can only present chances for better work conditions if the kinds and sources of risk are recognized by people engaged in their conception and implementation. It is imperative to acknowledge that mishapsthat occur during prefabrication component assembly are notintrinsic to the prefabrication process; rather, they are the consequence of human mistake, insufficient training, or othersite-specific elements. Clear communication, meticulous planning, stringent adherence to safety procedures, and appropriate training can all help to reduce these hazards andguarantee the safe assembly of prefabricated components. Prefabrication's safety benefits, like regulated manufacturing conditions and less work on-site, can frequently result in a safer building process overall.

III. METHODOLOGY

There are four main types of academic research that researchers can use to conduct and complete their various studies. The first type is Action (Applied) Research, where researchers focus on solving real-life problems using scientific methods. The second type is Qualitative Research, that focuses on collecting and analyzing data from observing people's actions and sayings. The third type is the Quantitative Research where researchers focus on developingand employing mathematical models, theories, and hypotheses related to as specific phenomenon as possible thus trying to quantify the problem to formulate facts. The fourth and last type is the Mixed Methods approach, where researchers can use qualitative and quantitative research together to conduct their research.

For conducting this research, Mixed Research Methods will be used to collect the appropriate amount of qualitative and quantitative data. Furthermore, in this research, web andpaper questionnaires will be designed, and interviews with experienced people will be held. Moreover, after collecting the necessary data, ANOVA and Delphi Method will be usedto analyze the collected information.

A. Research Methodology

To demonstrate and further explain the methods which will be applied to solve each research question is shown in the figure below.

B. Hypothesis

Prefabrication techniques are widely used in building projects, which benefits worker safety by lowering the number of accidents that occur on the job site, increasing adherence to safety procedures, and promoting overall worker well-being as compared to traditional construction methods. The following parameters should be measured to approve or reject the hypothesis: *Incident Rates:* Compare the frequency and seriousness of safety occurrences, such as mishaps, injuries, and near-misses, between building projects that heavily rely on prefabrication and those that use conventional construction techniques. *Safety Compliance:* Comparing prefabrication-using construction sites against those that don't determine the extent to which safety guidelines, laws, and best practices are followed. Indicators like the frequency of safety violations and noncompliance incidents should be measured. *Training and Guidance:* Compared to regular construction projects, evaluating the effectiveness of the safety education and training programs for the workforce involved in prefabrication

projects. Analyzing how well training works in preventing accidents and raising awareness of safety. *Null Hypothesis:* There is nosignificant difference in worker safety due to variations in incident rates between the two modes of construction. There is no significant difference in worker safety due to variationsin safety compliance by the whole organization in both methods of construction. There is no significant difference inworker safety due to variations in training and education related to prefabrication. *Alternative Hypothesis:* There is a significant difference in worker safety due to variations in incident rates between the two modes of construction. There is a significant difference in worker safety due to variations in safety compliance. There is a significant difference in workersafety due to variations in training and education related to prefabrication.

C. Questionnaire Development

To assess the worker safety of the prefabricated approach in the construction site, a structured questionnaire was created and sent to various site managers, project engineers, safety officials, and employees.

The questionnaire consisted of the following segments:Segment 1: Demographics

Segment 2: Workplace Safety Assessment Survey which isdivided into 3 sections.

The sections for Segment 2 included the following three variables: Incident Rates, Safety Compliance, Training and Education. The sections responses were then turned inrovalues to do the analysis section of the thesis.

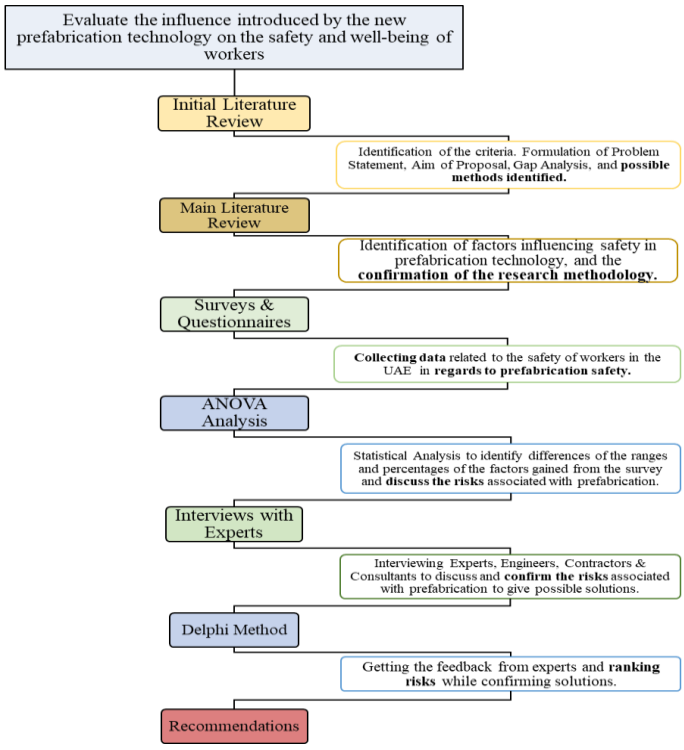
D. Sampling Design

The majority of the study's target group are project and site engineers who operate on building sites. There are two waysthat the questionnaire was created and designed:

Soft Copy: One hundred safety officers, engineers, managers,and laborers from the construction industry in the United Arab Emirates filled out the survey.

Hard Copy: Six papers are distributed to prefabricated professionals to solicit their opinions on the various construction techniques. The total sample obtained from thequestionnaire was *(n=106)*

Figure 1: Research Methodology Chart



E. Data Analysis Techniques

A three-way ANOVA was utilized to examine the association between the variables (Incident Rates, Safety Compliance, Training & Education) on Worker's Safety to meet the study'sobjectives and ensure its validity.

1. ANOVA Analysis (Analysis of Variance)

The ANOVA test is a way to determine if experiment resultsor survey are significant (Blockdyk, 2018). In other words, they help to figure out if you need to accept or reject the alternate hypothesis. Furthermore, evaluating groups to see ifthere is a difference between them.

The method will be applied to have a better understanding of the studied factors which have a significant influence on the safety of workers through prefabrication whether it has increased or decreased.

The impact of three independent variables (incidence rates, safety compliance, and training and education) on worker safety in the context of prefabrication can be examined using a three-way ANOVA (Analysis of Variance).

IV. RESULTS & DISCUSSION

A. Results from the Questionnaire

The questionnaire was delivered both online and in physical form to project managers and site engineers working onvarious building projects around the United Arab Emirates. Atotal of 106 replies were collected, and all pertinent data for this study was produced using the SPSS Statistics software. The demographics of the respondents who provided input forthis study are shown in the following section. Site engineers made up most responders (19.81% of the total), with the majority working in the building industry.

The largest group of responders, at 35.85% of the total, werethose with six to ten years of building experience. Followingthat, experience levels of 1–5 years and 11–15 years had yields of 21.70% and 21.70%, respectively. The remaining age groups 16–20 years old, over 20 years old, and younger than a year contributed 10.38%, 5.66%, and 4.72%, in that order. The largest group of, at 40.57% of the total, were in theresidential construction sector. Following that, commercial and industrial had the same percentage rate at 21.70%. Infrastructure/Transportation at 13.21% and Energy/Utilities at 12.26%. Other construction sectors had a uniform percentage of 0.94%. Most responses were from the private sector with a percentage of 54,72%. Following that with the government sector with a percentage of 23.58% and finally, the semi government sector with a percentage of 21.70%.

Most respondents work in organizations with more than 200 employees having a percentage of 63.21%. Following that with 33.02% working in organizations with 50-200 employees and 3.77% working in organizations with less than 50 employees. Dubai had the most respondents regarding the most experience in construction sites with 60 responses having a percentage of 56.60% and the lowest was Fujairah having 2 responses with a percentage of 1.89%. Thetable below showcases the percentages of the different emirates with the most experience from the construction siteprojects.

B. Cronbach's Alpha Reliability Test

To make sure that the results obtained are reliable,Cronbach's Alpha reliability test was conducted which is a measure of inter-rater reliability, where Cronbach's Alpha

≥0.6 indicates that the obtained data set is reliable.

C. Results from ANOVA (Analysis of Variance)

For Levene's test, we accept the Null Hypothesis of homogeneity of population variances since p = 0.115 which is greater than 0.05.The Levene's test showed that the variances of the groups were equal.*(F (10,88) = 1.616, p =*

0.115. To check the normality of our data, we can check the Skewness & Kurtosis of our data: Skewness

measures the lack of symmetry between a distribution or a data set. Kurtosis measure the peakedness and flatness of adistribution. For medium sized samples (50 < N < 300), weuse the z value range between -3.29 & 3.29 to checknormality of the samples. Looking into the Skewness &Kurtosis Table, we can derive that the z value for most pairsis between -3.29 & 3.29, there concluding that the data isnormallydistributed.3-Way ANOVA only requiresapproximate normal data because it is quite robust to violations of normality, meaning that the assumption can be alittle violated and still provide valid results. Since our data islarge (N = 106), using analytical tests such as "Shapiro-Wilktest of normality" will have a major drawback since thep-value decreases with the increase of sample size, meaningthat it will be less than 0.05. For all three variables (IncidentRates, Safety Compliance, Training & Education) thequantile-quantile plot (Q-Q plot) indicates that the gathereddata are normally distributed since all the points lie on thenormal line as shown in the graphs produced by SPSSSoftware Program. For normality of the residuals, since theShapiro-Wilk test has a p-value of 0.571, we conclude thatthe normality test is true since it is above 0.05. Regarding reporting the main effects, A factorial ANOVA [3-Way ANOVA] was conducted to compare the main effects of Incident Rates, Safety Compliance, and Training &Education [III] as well as their interaction effects on theWorker Safety Score [DV]. Incident Rates, SafetyCompliance, and Training & Education effects were allstatistically significant at p < 0.001 (This indicates that thereis a significant difference across all levels).

The main effect of Incident Rates yielded an effect size of 0.282, indicating that 28.2% of the variance in the Worker Safety was explained by Incident Rates.(F(2,88) = 17.240, p

< 0.001). The main effect of Safety Compliance yielded aneffect size of 0.324, indicating that 32.4% of the variance inthe Worker Safety was explained by Safety Compliance (F(2,88) = 21.087, p < 0.001).The main effect of Training & Education yielded an effect size of 0.423, indicating that 42.3% of the variance in the Worker Safety was explained byTraining & Education (F(2,88) = 32.304, p < 0.001).

For reporting the interaction, the interaction effect between Incident Rates and Safety Compliance was not significant (F(4,88) = 0.509, p = 0.729), indicating that there was no combined effect for Incident Rates and Safety Compliance on the Worker Safety. The interaction effect between Incident Rates and Training & Education was not significant (F(3,88)

= 0.393, p = 0.758), indicating that there was no combined effect for Incident Rates and Training & Education on the Worker Safety. The interaction effect between Safety Compliance and Training & Education was not significant (F(2,88) = 0.091, p = 0.913), indicating that there was no combined effect for Safety Compliance and Training & Education on the Worker Safety. The interaction effect between Incident Rates, Safety Compliance and Training & Education was not significant (F(1,88) = 0.074, p = 0.786), indicating that there was no combined effect Incident Rates, Safety Compliance and Training & Education on the Worker Safety. Furthermore, for the Post-hoc Test Results, as stated previously, the independent variable: Incident Rates, Safety Compliance, Training & Education are significant. Looking inside the pairs of the independent variable, we can concludethat all pairs are significant.

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V. AUTHORS PROFILE

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