Comparison between Modularization and Traditional Construction (Stick Built) in Gas Processing Facilities [1]

Hamad Aldossary and Badea M. Al-Saggaf

1. Introduction

The world of construction in oil & gas industry is continually evolving, with modular & stick-built constructions standing as two key methodologies. Construction of gas processing facilities is complex and capital-intensive, often susceptible to delays, cost overruns, and safety risks. Companies continually seek strategies to enhance efficiency and cost-effectiveness. Modularization, fabricating modules offsite (normally in shop) and assembling them onsite, has emerged as a viable alternative to traditional stick-built methods. The intention of this paper is to compare between the two construction methods by using real world data collected from actual construction projects and theoretical insights. The method of analysis that has been used in this paper is based on a comparative case study between two different projects but in the same location in which the evaluation factors are the total cost, schedule duration, and project outcomes. The research question was discussed by developing three different hypotheses. The first hypothesis was to evaluate and determine whether the modularized projects have a better cost effectiveness than the traditional construction projects (stick-built). The second was to compare the safety performances between the two projects and finally to compare the duration of the project for the two projects. A mixed-method research design was employed to test the hypothesis, and both descriptive and inferential statistics were conducted.

2. Literature Review

Previous studies have emphasized the advantages of modularization in industrial construction. According to Smith (2017), modularization reduces on-site labor requirements by up to 50%, leading to improved safety and faster project delivery (Smith, 2017). Gibb and Goodier (2019) highlighted modularized projects' logistical and planning complexities but confirmed significant cost savings in remote locations (Goodier, 2019). In a report by CII (Construction Industry

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Institute, 2011), modular construction showed a 6-20% reduction in total installed costs for petrochemical and gas projects (Lawson, 2014). However, challenges such as transportation logistics, design limitations, and initial capital requirements persist. The literature suggests that when properly managed, modularization offers superior outcomes in terms of cost and time efficiency.

3. Conceptualization and Theoretical Basis

As technology improves, so does every sector involve manpower and analytical processing ideas. The oil and gas companies are said to be in the business of trying to improve the efficiency, the quality of the projects performed, and the safety of anyone handling the process. According to (H&M, 2024), modularization has emerged as a compelling alternative in the construction sector in the global markets. Despite the industry inclining more toward stick-built procedures, it has been found that many projects are inclining towards a more advanced approach, and in this case, modularization comes into the picture. The authors argue that these changes are catalyzed by labor costs, skilled labor availability, and the necessity to take projects from rural areas where the impracticality of traditional methods is considered (H&M, 2024).

On cost comparison, in stick-built construction, the cost is potentially higher because of the labor involved. The number of labors assigned to the project might not achieve the maximum expected productivity due to site factors such as mobile equipment access, civil work, unavailable materials, etc.. This results in spending more cost on labors while desired output is not achieved. On the other hand, modular construction has lower costs due to efficiencies in both production and assembly lines at the factory shop. In modularization at the shop, the manpower requirements are less in comparison to sites due to availability of automated erection equipment such as tower cranes or automated bolt torquing machines. However, this type of construction needs assessment as a result of the dynamism of steel and transportation costs (H&M, 2024). According to (Dey, 2023) the construction costs are higher in traditional constructions compared to shop modular fabrication. On the contrary, there are overrun risks in the traditional construction approach compared to modular construction. This makes the traditional construction to be more expensive than modularization. In other words, the duration of utilizing the project's resources is longer in stick built due to uncertainty of site conditions while in the modular fabrication shops, those uncertain factors such as interface with other contractors or equipment access are eliminated.

On safety, (H&M, 2024) argued that there is a high risk due to prolonged onsite activities in traditional construction. This puts the lives of labors hard at risk. The modular construction is more controlled thereby, enhancing safety and reducing the risks of injuries. A comparison has been done in Jafurah Gas Projects between modularization and stick built in terms of safety as it can be seen below:

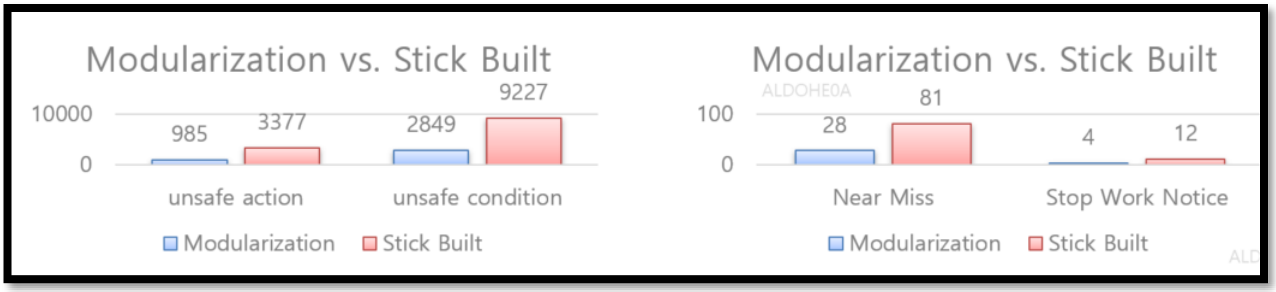

Figure 1: Safety Comparison

This research is rooted in project management theories, particularly those concerning cost control, value engineering, and lean construction. The conceptual framework hinges on Total Installed Cost (TIC) as the primary comparative metric, encompassing design, procurement, fabrication, transportation, and installation. The theory of constraints (Goldratt, 1984) is used to identify bottlenecks in both modular and stick-built approaches. Lean construction principles guide the evaluation of waste reduction and value maximization. This multi-theoretical basis ensures a comprehensive analysis of cost-effectiveness between the two construction methods.

4. Analytical Framework and Hypotheses

The hypothesis is an assumption or assertion that holds as true unless proven otherwise. The study employs a comparative cost-benefit analysis framework. To perform this, there will be a need to have different costs for comparison. The primary hypotheses are:

> *H1: Modularization costs lower Total Installed Costs than traditional stick-built construction in gas processing facilities.*
>
> *H2: Modularization reduces project schedules compared to stick-built construction.*
>
> *H3: Modularization improves safety performance due to reduced on-site labor.*

The first hypothesis will directly assess, both hypothetically and practically, whether there is a statistically significant difference in total costs for the two construction methods. This will mean that the mean of the total cost in modular construction will be statistically compared to the mean of the total cost in traditional construction.

The second hypothesis will be assessing the time duration spent on both construction and assessing whether modularization improves the project schedule. This means that a direct comparison will be conducted. It is known that the more days the construction takes, the costlier it becomes, and therefore, there will be a need to assess this based on the project duration.

The third hypothesis will assess whether safety has improved in modularization. The damages to human power are an increased cost, and therefore, to determine how safety of the personnel and the machines used in the construction, we will need to compare the two construction methods in gas processing industries.

5. Research Design;

Case Study: Shell Prelude FLNG vs. Chevron Gorgon LNG

Location: West Australia.

This research encompasses the use of a mixed-method design where both qualitative and quantitative data were analyzed. This method was deemed best because it provides a more comprehensive picture of the research hypothesis. It also balances the limitations of each method. Quantitative data that was used in this study was derived from project reports and financial statements of two gas processing facilities: the Shell Prelude FLNG for the modularized gas processing industry (Prelude, 2014) and the Chevron Gorgon LNG for the stick-built gas processing industry (Reddal, 2012). Once the two datasets are collected, the sample size is determined by the amount of data available. Therefore, for this study, a sample size of 60 was employed. This value was large enough since it was greater than 30, and therefore, it was deemed appropriate to run the t-test and other statistical tests that were needed. The qualitative data only involved determining whether the construction method in the given gas processing industries is modular or stick-built. The data was then combined with the quantitative data in columns and rows.

The variables used in the study were;

- **Project type:** This was measured as categorical with two levels (modular and stick-built). It determined the type of the project, and since we were comparing only two projects, both of them were included in the dataset.
- **Total cost:** This is a continuous variable, and the values are measured in millions.
- **Schedule:** This is the duration the project takes to completion. It is measured as continuous, and the values represent the time taken in months to complete a project.
- **Safety incidents:** This represents the incidents of safety incidents that have been reported. The variable is continuous in measure.
- **Percentage of rework:** This is measured as a percentage and represents the percentage of the work that was done and needed to be redone/modified again.

To answer the research hypothesis and the given research question, the above variables were used. All the variables directly or indirectly correlate with the cost of the two projects. Additionally, the motive, as indicated in the introduction, is to compare the two projects based on cost. Therefore, a comparative analysis was carried out. This involved the use of a t-test to compare the means for the total cost of the two projects (modular and stick-built). A t-test was used to test the hypothesis that there is no significant difference between the costs of modularization and stick built construction method. Additionally, descriptive statistics were also conducted to describe the data in terms of mean and standard deviation. To quantify the impact of modularization, linear regression analysis was conducted with total cost as the outcome variable and construction method, duration period, and rework rate as the response variables. The research also accounts for external factors such as location, climate, and regulatory environment to ensure a direct comparison.

6. Results and Discussions

Descriptive Analysis (Shell Prelude FLNG vs. Chevron Gorgon LNG)

Factor	Modularization	Stick-Built
Total Installed Cost	11,849M USD	15,065M USD
Schedule (Months)	47.6	60.19
Safety Incidents	0.30	0.62
Rework	3.91%	8.56%
Delay (Months)	2.2	5.5

Table 1. Descriptive Statistics for All Variables by Project Type.

A descriptive statistic was conducted to assess how the data was distributed. The analysis compared the modular and the traditional stick-built methods across all the key performances of the projects (i.e., cost, duration of the project, safety risks, percentage of rework, and delay in months). The average total cost for the modular project was smaller than the cost for the stick-built project. The cost is determined based on the utilized resources and the required quantity of materials. Moreover, modular projects in gas processing industries took less time than stick-built projects. The main reason for this is that the shop fabrication of modules allow better performance due to unavailability of site challenges such as interface with other contractors, permits issuance or equipment access. Additionally, there was improved safety performance in modular construction projects than in stick-built projects. On percentages of rework, modularization showed less rework percentage compared to stick-built rework percentage. Also, the modular project construction showed fewer project delays compared to the stick-built project.

7. Conclusions

Modularization in gas processing facilities proves to be more cost-effective than traditional stick-built construction when evaluated through total cost, labor efficiency, and project schedules. The evidence from the modular and traditional projects supports the argument that modularization offers significant financial and operational advantages, especially in remote or logistically challenging areas. While modularization requires meticulous planning and upfront investment, the long-term savings and performance improvements justify the approach. Project managements should consider modular strategies not just as a construction alternative but as a fundamental shift in project execution philosophy. Future research should explore broader datasets and include more diverse project environments to further validate these findings.

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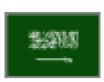

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