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Research paper

Technology foresight in Modular Construction Shipbuilding Industries: The Case of Malaysia's Shipyard

Ahmad Alliff Anuar Mokhtar[1], *, Mohamad Abu Ubaidah Amir[1], Ainnur Hafizah[2],Abdul Halim[1]

[1]Faculty of Science and Defence Technology, National Defence University, Malaysia, Kem Perdana Sungai Besi, 57000 Kuala Lumpur, Malaysia.
[2]Faculty of Computing and Informatics, University Malaysia Sabah, 87000 F.T. Labuan, Malaysia.
**Corresponding author E-mail:ahmadalliff@gmail.com*

Abstract

The shipbuilding and ship repair industry in Malaysia involves designing, building and constructing, repairing and maintaining, converting and upgrading of vessels as well as marine equipment. It is getting larger and always evolve in line with the development of technology such as with the latest technology which is embedded in modular construction. Nowadays, the modular construction approach in shipbuilding is already known worldwide. However, adoption of this method in Malaysia is still minimal in term of scale and it is not comprehensive. The latest, Boustead Naval Shipyard (BNS) was entrusted to build 6 Littoral Combat Ship (LCS) for Royal Malaysian Navy (RMN) in BNS in Lumut, Malaysia. One of the advantages for this contract is the technology transfer which also includes the modular construction. The study is conducted using the qualitative and quantitative method. Qualitative data collection method that used in this study includes individual interviews, and observations to examine the perspective from the higher management level on how to assess modular construction shipbuilding and hence to examine the factors through implementation and the effectiveness towards Malaysia's shipyard of modular construction shipbuilding. For quantitative data collection method include various forms of surveys – online and form survey. Respondents are only from the higher management level. This data will be transformed into usable statistics using statistical software, Statistical Package for the Social Sciences (SPSS). Thus, this study is to analyse the technology and the viability in which to investigate of the existing business sustainability construction shipbuilding in Malaysia's Shipyard. The result can be used for the better understanding the modular construction and its impact on the production process in Malaysia, and also improve the technology and method of modular construction shipbuilding in Malaysian shipyard.

Keywords: *Modular Construction Shipbuilding, Shipbuilding, Malaysia Shipbuilding Prospect*

1. Introduction

The maritime industry is a role play in associate for Malaysia's economic development. This is regard to the statement which shipbuilding ship repair (SBSR) industry has been precisely recognized in the Third Industrial Master Plan (IMP3) in place of an industry that can gives something to the country's wealth from the transportation area [1]. The shipbuilding industry of Malaysia is getting larger and shipbuilders are adapting with the latest technology. For each project to achieve successfully, it is important to manage a project within the constraint. The major constraint that should be considered is cost, duration time to complete the project, safety aspect for workers and the quality of the project. In one hand, all the constraint can be achieved via a concept of modular construction.

Modular construction is pre-packaging a collection of equipment (systems or components) for the purpose of their assembly and check-out prior to delivery to the ship for installation and for ease of installation and removal of the package (module) [2]. It also can be defined such as seizures the partition of the ship into blocks, subdivisions, and units as part of the process in ship production [3]. The concept of modularization is closely related to several other systems concepts and technologies that have received considerable attention lately. These concepts include product platform technologies, product architecture, which denotes the scheme by which the functions of a product are allocated to physical components, configuration based design, mass customization, and Lean Manufacturing Principles. Units can be established in the varied diversity of techniques like outfit and equipment modules, hull assemblage blocks, equipped hull blocks and equipped panel assemblies.

2. Modular Construction History

The start of the history of South Korean shipbuilding industry was very unique so called 'started with nothing'. Founded in 1973, HHI (Hyundai Heavy Industries), the first and largest shipbuilding history. HHI's first order, a 260,000 DWT VLCC (Dead Weight Ton, Very Large Crude Oil Carrier), was completed concurrently with the grand opening of the shipyard. Under strong support from the South Korean government's industrial policy that emphasized heavy industry in the 1970's and 1990's. HHI has been able to expand its capability both in quality and quantity, as well as emphasizing workforce training. The world's second and third largest shipyard, SHI (Samsung Heavy Industries) and DSME (Daewoo Shipbuilding & Marine Engineering) respectively, were also founded and expanded their facilities during a similar period of time. In 2000, South Korean shipbuilder's family achieved status

as the world's number one shipbuilder surpassing their Japanese peers in terms of orders received and backlog orders. As of today, despite fierce challenge from China, South Korea has maintained a leading position due to superior technology, strong R&D investments and quality management systems [4].

3. Modular Construction Concept

Modular construction was obtained from the idea of the lean production. It is one of the theories in ship industry. It is as first proposed by the U.S shipbuilding industry which covers the entire shipbuilding contract from the beginning of assembly to the delivery of the finalized ship that involves the whole process of complete motivation and organization of all employees. It is a continuous process to improve and to get perfect the process of ship construction by reducing wastage, shipbuilding recycles time, shipbuilding costs in order to improve shipbuilding quality. To make it competitively, the diverse perceptions and approaches be existent in the scientific field of refining shipyard productivity [5]. Many world class shipyards have been practical in with a various degree of success to plan for construction concept [6]. In order to maintain survivability, product mixes denote the reality of many shipyards. The plan for fabrication methods have presented its combination primary in the ship plan procedure produces goods at several forms of shipyards, plus medium sized shipyards. Product mixtures signify the certainty of several shipyards in demand toward preserve survivability. Similarly, the plans for fabrication approaches have presented its integration primary in the ship design procedure yields goods in several forms of shipyards, including medium sized shipyards.

Furthermore, to completely yield advantages of repeatable interim products, the designs for fabrication perception as engaged by the utmost radical world shipyards need a shipyard with a Product Work Breakdown Structure (PWBS). The most advanced shipyards, they will practice of machinelike or robotic welding to make them achieve 90% of entirely main panel welding work concurrently. In addition, a fresh practice which is beneficial for shipyard organization while determining upon shipbuilding technology and technology developments is applying the design for assembly concepts with risk analysis. Determination of technological limitations for the plan explanation of a shipbuilding fabrication suite additional enriches the production of shipyards with product mixes. The figure 1 and 2 below show the modularization concept.

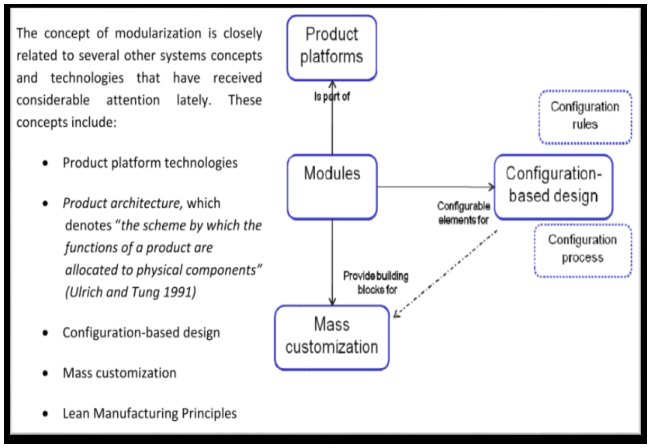


Figure 1: Concept of Modularisation [3].

Figure 2: Modular construction concept [7]

4. Comparison between Modular Construction and Conventional Shipbuilding.

This section is devoted to a discussion of conventional shipbuilding with that of ships constructed using modular construction methods. The comparison between modular construction and conventional shipbuilding is shown in Table 1. The traditional organization of shipbuilding, dating from the days of wooden ships, was constructing the ship in place, working on each functional system of the ship in turn. First, the keel over was placed, then and there the frame initiated, and so on. When the body of the ship or hull was closely ample, equipping of the ship arose, as exposure to air (ventilation), tubing, electrical components, and machinery. Systems were fitted. Traditional shipbuilding results from a systems approach for a ship design. Each system has its own drawings, and outfit drawings are generally not issued until hull construction is well underway. Work suite fillings are moderately huge which make difficulties every effort to reach unchanging and synchronized work streams. Work crews commonly compete with each other for admittance to a work space [8].

This leads to redundant temporary services, e.g., staging, welding cables, compressed-air hoses and flexible ventilation ducts, leading to unsafe working conditions. Further, utmost above work is still completed by workers getting above their heads. All of the foregoing results in the traditional shipbuilding method being a slow, laborious, and expensive process. Figure 3 shows the comparison assembly method or modular construction shipbuilding method between the conventional shipbuilding methods. Furthermore, figure 4 shows the timeline of modular construction shipbuilding and conventional shipbuilding.

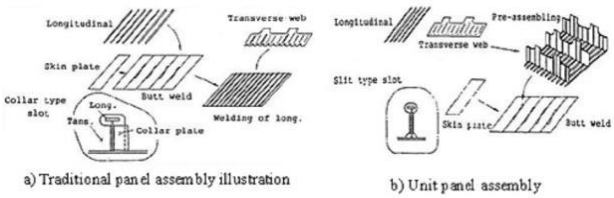


Figure 3: Comparison between modular Construction and conventional Shipbuilding [5] [9].

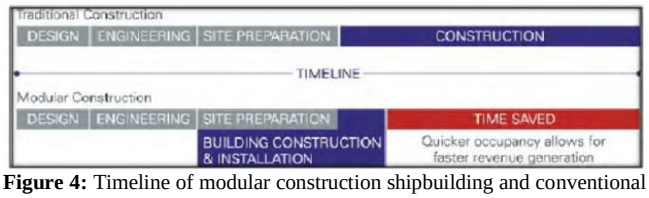


Figure 4: Timeline of modular construction shipbuilding and conventional shipbuilding [10].

Table 1: Theoretical Comparison Between Modular Construction Shipbuilding and Conventional Shipbuilding [5] [6] [11].

Types of Method	Modular Construction	Conventional Shipbuilding
Focus	Customer	Product
Operations	Synchronized flow and pull	Batch and queue
Overall aim	Eliminate waste and add value	Reduce cost and increase efficiency
Quality	Prevention (built in by design and methods)	Inspection (a second stage after production)
Business	Flexibility and adaptability	Economies of scale and automation
Strategy Improvement	Workforce driven continuous improvement	Expert driven periodic improvement
Time	More time efficient	Less time efficient

The table 1 shown the theoretical comparison between modular construction shipbuilding and conventional shipbuilding. The antithesis to traditional shipbuilding method is the modern shipbuilding utilizing modular construction method. A ship as a total system/basic design is transformed into a zone oriented design that using a product-oriented design process. Before the construction begins, detailed of design must be completed first. Integrated hull construction, outfitting, painting, and pipe work process lanes are established for the production of interim products leading to the erection of a ship in building the dock. There is basically no competition by workers for work area access because zone-oriented arrangement controls the stream of work on the numerous work process lanes [8]. Majority of the work is done by down-hand. Work packages are idyllically sized for two workers to complete in a week.

Lastly, to make sure that is directly related to work completed, zone orientation provides accurate progress reporting and cost collection. Therefore, managers can forecast work remaining and resources required. All of the preceding contributes to a shipbuilding method that is faster, less labour intensive and less expensive [8]. Shipbuilders who desire to remain competitive are incorporating and adapting modular construction method based on their facilities capabilities and limitations.

5. Modular construction shipbuilding in Malaysia

According to Malaysia Shipbuilding and Repair 2015 and 206, similar to other parts of the world, the Malaysian shipping industry had suffered amid the global recession and performance declined in major shipping trades. As demand for shipping services fell, SBSR industry players faced very challenging market conditions [1]. Since 2010 until mid-2014, the O&G sector remains favourable after experiencing a low cycle in 2008/2009 underpinned by high oil prices and major projects by local and international players. The O&G sector is one of the strongest driving forces of the local SBSR industry. Based on this situation, shipyards have started diversifying their SBSR business into activities that support offshore demands such as structure fabrication, ship conversion (i.e. Floating Production Storage and Offloading (FPSO), Floating Storage Offloading (FSO), Floating Storage Unit (FSU)), rig building, platform repair and maintenance as well as ship chartering.

According to the number of Domestic Shipping Licenses (DSL) issued by the Ministry of Transport (MOT), the number of vessels operating within Malaysian waters is on an uptrend. Despite the high number of vessels, local shipyards are still unable to capture the repair market as foreign ship owners prefer to dock their vessels at home port or shipyards in Singapore and Batam, Indonesia. Again, the faster turnaround is the main reason especially to ship operators that are servicing the O&G sector. In Malaysian Development that focuses in the shipping industry, the main objective is to develop a niche market and subsequently migrate shipbuilding, ship repair and parts and component manufacturing activities towards higher value-added services.

Malaysia has been actively involved in shipbuilding and ship repair. Compared to the advanced countries of the shipbuilding industries such as Japan and Korea, Malaysia's capacity is currently lower in many ways. One of the major limitations lies in the shortage of locally trained marine engineers and naval architects who are needed to support the development and growth of the industries [12]. The shipbuilding industry of Malaysia is getting larger and shipbuilders are adapting with the latest technology. The shipbuilding technology is growing at a fast pace efficiently as construction time savings being the most important factors in ship construction. The Modular construction approach in building a vessel is a common method nowadays. However, more focus is required in order to improve the performance of this construction method in Malaysia.

It is being approved by the result in prefabricated modular building product that is faster, more affordable and environmentally-friendly, with all the same architectural aesthetics you would expect from traditional building methods. After the module is completed and has passed the inspection by quality control department, the module is ready for erection process on board as shown in figure 5 and figure 6 below. (This process is taken at Kencana Marine in KM2 (Kencana Mermaid 2) project). Modular construction is the most time - saving method in use nowadays as shown in figure 5 & figure 6.

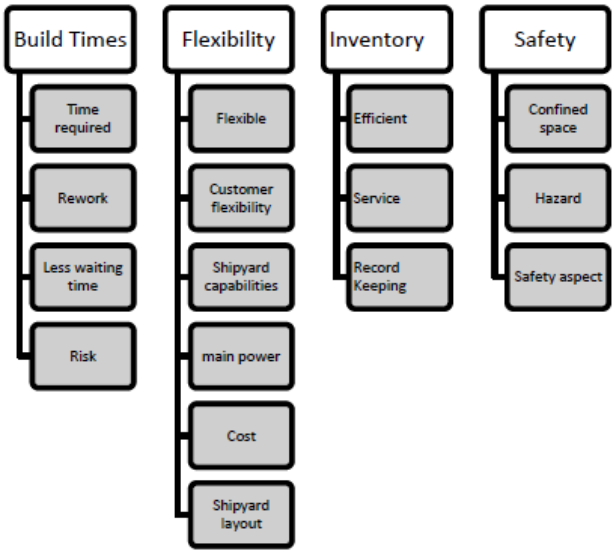
Figure 5: Picture of Modular Construction at Kencana (Erection Process) [10].

Figure 6: Picture of Module (Lifting Process) [10].

6. Methodology

6.1 Concept of the questionnaire

Based on the foregoing discussions, the items in the items in the questionnaires are set to in order to conduct an overall analysis from multi aspects to indicate the characteristics of the Malaysia's shipbuilding companies selected. The items include not only factors related with the build time of the modular construction shipbuilding in the shipyards selected, but also the inventory, flexibility and safety of modular construction shipbuilding in the shipyard selected.



The research was conducted to measure the factors contributing and the relationship between the factors through implementation and the effectiveness towards Malaysia's shipyard. The mean factors are being analysed using descriptive statistics such as mean and standard deviation. The researcher takes into consideration of factors that contributed through the implementation of modular construction shipbuilding towards Malaysia's shipyard.

Next, the correlation was used to identify the nature, direction and significance of the relationships of the variables that were being used in the research [13]. In this research, the researcher analyse the correlation between modular construction shipbuilding factors through the implementations and the effectiveness towards Malaysia's shipyard. Furthermore, regression analysis also was used to explore the relationship between on continuous dependent variable and a number of independent variables usually continuous or even otherwise.

6.2 Questionnaires Method

The objective of questionnaires method is to develop an appropriate framework to extract critical factors for the research topic especially strength and weaknesses of both modular construction shipbuilding and conventional shipbuilding approach at Malaysia's shipyard. The target group were from high-level management from the 5 biggest shipbuilding companies in Malaysia which is accorded Class A and AA and are registered with the Ministry of Finance Malaysia.

The questionnaires distributed to ten people from different department in each shipyard selected. Therefore, the questionnaires will be filled automatically using the google survey form which that have been emailed to the five biggest shipyards in Malaysia chosen.Survey items were measured on 5-point Likert type scales [14]. Respondents may be offered a choice of five pre-coded responses with the neutral point being neither agree nor disagree. The Likert Scale is used to allow the individual to express how much they agree or disagree with a particular statement. The questions in the survey were modified from Hamada and Van De Ven instrument for measuring organizational effectiveness [15] [16].

6.3 Interview Method

The interview session is conducted for chosen candidates' correspondent. Interview candidates among high-level management personnel from the five biggest shipyards in Malaysia which is in terms of capacity in building merchant ships. There were 5 biggest shipyard which is accorded Class A and AA and are registered with the Ministry of Finance Malaysia. This method associated with questionnaires method for extending data collection.

3.4 Observation Method

The subject observed in this study are the 5 biggest shipbuilding companies in Malaysia which is accorded Class A and AA and are registered with the Ministry of Finance Malaysia. Malaysian shipyard is using the concept of modular construction shipbuilding. However, the level of use, is still too low compared to other countries. Malaysian shipyards nowadays, experienced an era in which the economic downturn and lack of large shipbuilding projects. The Shipyard in Malaysia today focuses mainly on ship repair and ship maintenance.

3.5 Validity and Reliability of Instruments

The instrument used in this study was tested for validity and reliability to a high- quality measure. Reliability and validity of a measurement instrument were essential because the absence of these qualities could explain why the researcher acts incorrectly in accepting or rejecting the research hypothesis.

A pilot study was conducted and the questionnaires were distributed to 15 respondents. The respondents involved in this pilot study were then excluded from the actual respondents in the population. The pilot study was conducted to make sure that the respondents understood the items in the questionnaires. It is also to ensure that there was no confusion in the questions that would lead to ambiguity. The pilot study also was conducted to estimate the time taken by the respondents to answer the questionnaires.

The reliability of the measure was established by testing for both consistency and stability [13]. Consistency indicated how well the items in a set were positively correlated to one another. The reliability is a concept, but it was also a practical measure of how consistent and stable a measurement instrument or a test might be [17]. In this research, internal consistency was used to ensure the reliability of the instruments. Internal consistency was the measure of how consistently each item measures the same underlying construct [17].

7. Results & Discussion

This data will be transformed into useable statistics used statistics software which is Statistical Package for the Social Sciences (SPSS). The research used two types of statistics which were descriptive statistics and inferential statistics. Descriptive statistics focus on statistics that illustrate the phenomena of interest [13]. While inferential statistics were being used when the research needs to know how variables relate to one another or any differences exist between groups [13]. It also focused on the statistical results that would lead the researcher to make inferences from sample to the population.

Table 2: Frequency of the company's profile

Company	Frequency	Percent
Shipyard A	10	20.0
Shipyard B	10	20.0
Shipyard C	10	20.0
Shipyard D	10	20.0
Shipyard E	10	20.0
Total	50	100.0

The description of the profile of companies is illustrated at table 2 above. The frequency distribution is being used to get the entire exact figure for the companies' profile. The companies involved which are shipyard A, shipyard B, shipyard C, shipyard D, and shipyard E which are accorded Class A and AA and are registered with the Ministry of Finance Malaysia.

7.1. Factors Contributing through the Implementation of Modular Construction Shipbuilding towards Malaysia's Shipyard.

There are four factors that contributing through the implementation of Modular Construction Shipbuilding towards Malaysia's Shipyard which was build times, safety, flexibility and inventory. Table 3 shows the factors arranged from the highest to the lowest. Mean factors are being analyzed using descriptive statistics such as mean and standard deviation. The highest factors that contributed through the implementation of modular construction shipbuilding towards Malaysia's shipyard was build times (M = 4.29, SD = .50) followed by inventory (M = 4.02, SD = .44). Another factor contributing through the implementation of modular construction shipbuilding is flexibility (M = 4.00, SD = .44) followed by safety (M = 3.69, SD = .57).

Table 3: Factors Contribute Through the Implementation of Modular Construction Shipbuilding in Malaysia's Shipyard.

Factors	Mean	Std. Deviation	N
Build Times	4.2960	.50019	50
Inventory	4.0200	.44878	50
Flexibility	4.0033	.44606	50
Safety	3.6920	.57030	50

From the table 3 above, the findings showed that most of the organization take a high consideration on build times. Modular constructions shipbuilding build time typically is 50% - 60% less than traditional on-site construction, to an earlier return on investment and saving in preliminaries [5]. Standardization was found to have considerable potential for reducing the time associated with ship construction. Subsequently from that, it is also less unnecessary motion which is when workers are not efficient because have to walk or moving in order to do their jobs [5]. For example, workers have to walk to get a tool or piece of material. Due to unnecessary motion, also will make workers tiring and demotivate. Further, pointless signs are linked to workforces and facilities outline. For instance, shipyards must constantly attempt to lessen overhead welding and get the best out of down welding [5]. Overhead welding is advanced hard for workforces, includes extra time and is less competent than down hand welding.

The inventory factor as second factors also affect from the implementation of modular construction shipbuilding in Malaysia's shipyard which is unnecessary materials and equipment's from the traditional shipyard cause the inventory in storage is to be full [5]. By smart inventory modular construction shipbuilding method avoiding the inventory in storage to be full, it will assist by reducing storage area, reducing storekeeper time requirements and reducing record keeping. Besides, storekeeper can provide quicker service.

Other than that, the flexibility also one of the factors affect from the implementations of modular construction shipbuilding in Malaysia's shipyard. Example for flexibility which was once the requirements have some amendments, prefabricated modules can be taken to pieces and the units repositioned or overhauled for new procedure, however decreasing the request for raw materials. For outcomes, it will lessen the total of energy used to produce a unit to encounter the new necessity.

Next, the safety more slightly neutral result. This is because the safety aspect is come from attitude. The attitude of employees more contributing to the safety.

7.2. Relationship Between Modular Construction Shipbuilding Factors from the Implementation In Malaysia's Shipyard Through the Effectiveness

In order to test the relationship, the factors contributing through the implementation of modular construction shipbuilding in Malaysia's shipyard were computed for overall mean for every factor. The same procedure was carried out for acceptance. Table 4 showed the correlations of modular construction shipbuilding factors through the implementation and acceptance. The relationship between modular construction shipbuilding factors and acceptance was tested using Pearson product moment correlation coefficient. Table 4 shows that there was a positive and significant relationship between safety (r= .31, n=50, $p < .05$, p = .029) and flexibility (r= .31, n=50, $p < .05$, p = .031) with acceptance.

Hypothesis for research question predicts that there was a relationship between modular construction shipbuilding factors and acceptance. From the results, it shows that there was a relationship between the two variables which were safety and flexibility with acceptance. Therefore, the null hypothesis that there is no significant relationship between modular construction shipbuilding factors through the implementation and the effectiveness towards Malaysia's Shipyard is rejected.

Table 4: Correlations of modular construction Shipbuilding Factors Through The implementation and acceptance

		Build Times	Safety	Flexibility	Inventory	Acceptance
Build Times	Pearson Correlation		.143	.486**	.331*	.167
	Sig. (2-tailed)		.322	.000	.019	.247
	N		50	50	50	50
Safety	Pearson Correlation			.199	.104	.309*
	Sig. (2-tailed)			.165	.471	.029
	N			50	50	50
Flexibility	Pearson Correlation				.662**	.305*
	Sig. (2-tailed)				.000	.031
	N				50	50
Inventory	Pearson Correlation					.179
	Sig. (2-tailed)					.214
	N					50
Acceptance	Pearson Correlation					
	Sig. (2-tailed)					
	N					

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

The results of the Pearson correlation analysis in table 4 above indicated that there was a significant relationship between factors from modular construction shipbuilding implementation and the effectiveness towards Malaysia's Shipyard. There were relationships between the four independent variables of build times safety, flexibility and inventory to the dependent variables which was acceptance.

Referring to table 4, there were a relationship between build times and flexibility. Flexibility is the main cause leads to short building times in modular construction shipbuilding. The build time of the shipbuilding is closely related to flexibility. One of it is the customer needs. The purpose is to let customers pull value through the enterprise by understanding what the customer needs and produce to meet the real demand. From this situation, it can save time.

There is also a correlation between build times and inventory. This is because, from the modular construction inventory, the shipyard layout was different with the conventional shipyard layout. The shipyard layout is more efficient and reduce the record keeping for the inventory section to check the raw materials. The modular method relies on a pull type production system, where only the parts that are needed are present, plus a minimal number of additional units for the approaching work in progress. From that, it is more efficient and saving the time.
Subsequently from that, it is also a correlation between flexibility and inventory factor. The systematic shipyard layout provides the flexibility for the inventory.

7.3 Regression Analysis of Four Independent Variables

The regression analysis using enter method was conducted on the data to investigate the independent variables that would significantly explain the variance in acceptance. There were four independent variables which were build times, safety, flexibility and inventory. By analysing using the enter method, none of the independent variables was found to significantly explain the variance in acceptance.
From the results in table 5, it shows that slightly to less value of the independent variables of build times, safety, flexibility and inventory significantly explain the variance of the effectiveness of modular construction shipbuilding in Malaysia's shipyard. Therefore, the null hypothesis that there is no significant relationship between modular construction shipbuilding implementation and the effectiveness towards Malaysia's Shipyard is accepted.

Table 5: Estimates of coefficients for the model

Factors	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	2.296	.547		4.196	.000
Build Times	.006	.105	.009	.058	.954
Safety	.151	.082	.257	1.836	.073
Flexibility	.202	.150	.269	1.347	.185
Inventory	-.022	.136	-.029	-.158	.875

From the results of multiple regression analysis in Table 5, it is clear that none of the independent variables influential to the variance of acceptance. This result was being proved by the interview session with the high-level management of the shipyards. The main factors that contributing from the implementation of modular constructions shipbuilding in Malaysia's shipyard is technology, new technology need to be stressed in Malaysia's shipyard. In Malaysia, the biggest shipyard also still lacks of technology [18]. Otherwise, the modular construction shipbuilding in Malaysia's shipyard is still not effective because of the plan of modular construction project is dissimilar from the technique of project planning supported out by conservative methods. Hence, more emphasis should be specified to the project because the complexity of modules designs. It needs be conducted more specifically because modules need additional complex engineering design [19] [20] [21] [22].
Furthermore, terrific investment budget is also one of the drawbacks in applying modular assembly of this shipbuilding. The investment budget is similar as the application of modular assembly procedures for extra industries like construction of buildings [19] [23] [24] [25]. Besides, shortage of information about this technique is also one of the restraints that cause this method is not applied.

8. Conclusion

The effectiveness level of modular constructions shipbuilding in Malaysian shipyard still low, compared to the other Asia Shipyard, such as Singapore, Japan and South Korea. The factors that differ the development of modular practices are not only exist in the technological ability, but also involve various factors, including human resources, education system, management and other supporting industries. The analysis gives an insight view for the better understanding the modular construction and its impact on the production process in Malaysia. Thus, the result can be used to improve the better future for shipbuilding technology in Malaysian shipyard.

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