A Review of Modular Construction Shipbuilding in Malaysian Shipyard

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ABSTRACT

The shipbuilding and ship repair industry in Malaysia comprises of designing, building and assembling, repairing and maintaining, transforming and advancement 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. The modular construction approach in building a vessel is a common method nowadays. The latest, Boustead Naval Shipyard (BNS) were 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. Thus, this paper shows the contribution to the modular construction resulting in Malaysia Shipyard. The result can be used for the better understanding of modular construction and its impact on production process in Malaysia, and also improve the technology and method of modular construction.

KEY WORDS: Modular construction, shipbuilding, Malaysia’s shipbuilding prospect

1.0 INTRODUCTION

The maritime industry consumes 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 ship builders 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 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 varied diversity of techniques like outfit and equipment modules, hull assemblage blocks, equipped hull blocks and equipped panel assemblies.
2.0 LITERATURE REVIEW

2.1 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 industry. 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 expend 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 Korean has maintained a leading position due to superior technology, strong R&D investments and quality management systems [4].

2.2 Modular Construction Concept
Modular construction was obtained from the idea of the lean production. One of the theories in ship industry is lean production theory. 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 continuously process to improve and to get perfect the process of ship construction by reducing wastage, shipbuilding recycle 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 has been practical in with 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 needs a shipyard with a Product Work Breakdown Structure (PWBS). The most advanced shipyards, they will practice of machineline 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 technique 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.

Figure 1: Concept of Modularization
Sources: [3]

Figure 2: Modular Construction Concept
Sources: [7]
2.3 Value Adding Activity
An activity that transform shapes or converts raw material to meet customer requirements [8].

The three criteria for a Value Adding Activity are [9]:
1. The step transforms the item toward completion
2. The step is done right the first time (not a rework step)
3. The customer cares (or would pay) for the step to be done

2.4 Non – Value Adding (Wastes)
The term “non-value-adding activity” has been used commonly by researchers in literature concerning to lean production [10]. The non-value-adding activity is a term used to distinguish between physical construction waste found on-site, and other waste that happens during the construction process. An amount of classifications of waste are available [11]. Non value-adding activities or waste are consist of all those actions that produce costs, direct or indirect, and take time, resources or require storage but do not add value or progress to the product [8].

2.5 Modular Construction Process
Modular construction procedure is a common methods applied in shipbuilding industry. Modular constructions, or prefabricated construction, are a procedure that practices a prefabricated building process which gathered on-site to create a stable or temporary prefab building. Modular space earns lots of benefit of a well-ordered fabrication surroundings joined with the plan flexibility of old-style structure procedures to yield superior stable or impermanent prefabricated structures for some request [6]. The outcome is a prefabricated modular building product which is more rapidly, more reasonable and environmentally-friendly, consists of all the identical architectural aesthetics one would assume from old-style structure procedures.

![Figure 3: Flow chart of Modular Construction Shipbuilding Process Sources: [12] [13]](image)

2.6 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 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 [14]. 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.

<table>
<thead>
<tr>
<th>Types of Method</th>
<th>Modular Construction</th>
<th>Conventional Shipbuilding</th>
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</thead>
<tbody>
<tr>
<td>Focus</td>
<td>Customer</td>
<td>Product</td>
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<tr>
<td>Operations</td>
<td>Synchronized flow and pull</td>
<td>Batch and queue</td>
</tr>
<tr>
<td>Overall aim</td>
<td>Reduce left-over and add value</td>
<td>Decrease budget and upsurge effectiveness</td>
</tr>
<tr>
<td>Quality</td>
<td>Protection (built in by plan and procedures)</td>
<td>Assessment (a second stage after fabrication)</td>
</tr>
<tr>
<td>Business</td>
<td>Flexibility and adaptability</td>
<td>Economies of scales and computerization</td>
</tr>
<tr>
<td>Strategy Improvement</td>
<td>Workforce driven endless development</td>
<td>Professional determined intermittent development</td>
</tr>
<tr>
<td>Time</td>
<td>More time efficient</td>
<td>Less time efficient</td>
</tr>
</tbody>
</table>
2.7 Advantages of Modular Construction Process

2.7.1 Less Overproduction
Overproduction is the wickedest of the seven wastes of lean manufacturing (7 Muda’s). It creates products in excessively great an amount or formerly it is truly required foremost to disproportionate inventory. Overproduction also is the poorest of the seven wastes because it conceals all of the additional problems within the procedures [15]. Producing faster than the rate of consumption and make more product more than the materials needed for the shipbuilding. Otherwise, it will facilitate more routine activity and familiarity with fabrication and assembly.

2.7.2 Smart Inventory
Unnecessary materials and equipment’s cause, the inventory in storage is to be full [5]. By 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.

2.7.3 Less Unnecessary Motion
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 lessening overhead welding and get the best out of down welding [5]. Overhead welding is advance hard for workforces, includes extra time and is less competent than down hand welding.

2.7.4 Less Waiting Time
Workers being idle between operations, they need to wait for a machine to cycle or waiting for the preceding operator to finish their work [5]. For example, workers from other section have to complete with others section in order to use machinery and equipment to avoid bottleneck. Results from this situation will decrease the quality of the end product.

2.7.5 Flexibility
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.

2.7.6 Less Correction
Scrap, rework, sort, & repair add unnecessary costs [5]. In modular construction, the accuracy and competitiveness is needed by every worker to avoid correction which may lead to unnecessary time consumption. Other than that, it will reduce preventive maintenance time.

2.7.7 Conveyance
Unnecessary transportation can also increase money and time consumption [5]. Modular construction concept less needed transportation to bring modules from one station to another.

2.7.8 Short Build Times
Typically is 50% - 60% fewer than old-fashioned on-site manufacture, to an former return on investment and redeemable in beginnings [5]. Standardization was found to have considerable potential for reducing the time associated with ship construction.
2.7.9 Low weight
Modular construction is around 30% of the load of conservative building materials construction while matched to site construction [5]. Modifications in materials can decrease the weight of building modules, which at the same time make it stress-free to control, transport and set up.

2.7.10 Superior Quality
Modular construction concept accomplished by factory-based quality mechanism and predesigned of alike units. Modular construction methods are based on design for production (DFP) [5]. Base from the previous experiences and projects, the workers already knew and understand quality control needed for similar modules. As a result, it will provide better quality of the end product.

2.7.11 Economy of Scale
Duplication of prefabricated units indications to substantial economy of scales in fabrication [5]. By maximizing the use of common structure and components thoughts ship architecture and within a class were found to be potentially very effective.

2.7.12 Environmentally Less Sensitive
Competent factory manufacture procedures are greatly fewer inefficient and setting up is less troublesome on site. In modular construction technique, declines in material unused, air and water pollution, dust, and noise, and total costs cause by fewer job-site.

2.7.13 Reduced Site Labor Requirement
The assembly and final crews, that set up and comprehensive prefabricated buildings, comprise smaller amountworkforces on site than customary constructions [5]. From this situation, we can see that it is also will reduce the need for minor supervisory decisions.

2.7.14 Safer Construction
Modular construction sites have showed to be considerably harmless than traditional on-site building and it is a safer substitute [5]. During conventional shipbuilding, process of overhead welding is always used. Overhead welding is more difficult for workers and sometimes dangerous. Conventional shipbuilding workforces frequently work in fewer than ultimate situations allocating with extremes temperature [6]. Moreover, the possible for injury plus falls, the utmost common labor site hazard, is much greater.

2.7.15 Reduced Professional Fees
Consistent plan particulars for modular streamline and lessen the necessity for dedicated plan idea. Many of the benefits of standardization could be achieved by utilizing standard interfaces for mounting equipment and by placing constraints on equipment geometries and dimensions [5].

2.7.16 Less Over Processing (Inappropriate Processing)
Over processing involves consuming the unsuitable equipment and procedures for accomplishment a job [5]. For example, throughout the association of a block, inappropriate processing indications to countless man hours than needed and should be escaped.

2.8 Disadvantages of Modular Construction

Shipbuilding

2.8.1 Project Planning
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 [16] [17] [18] [19].

2.8.2 Transportation Restraints
A significant part should be highlighted by the transportation logistics in advance taking steps to begin a modular technique of construction of this shipbuilding. It is in line for some measures should be engaged to evaluate the boundaries of transportation in the module area [20] [21]. It is also an addition for learning the common transportation rules, special allowance traffic control desires (e.g., staging areas, etc.).

2.8.3 Negative perceptions
In some literature, the negative perception in construction methods always is highlighted. It is a substantial factor that obstructs the fast development of off-site construction methods all around the world. Nevertheless, they are totally dissimilar [22]. Non-existence of consciousness on the advantages and unlike possibilities presented by off-site construction method from the users can affect the market request and consequently the progress of these practises [23].

2.8.4 High Initial Cost and Site Constraint
Terrible 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 [16] [24] [25] [26]. Besides, shortage of information about this technique is also one of the restraints that cause this method is not applied.

2.9 Basic Principles of Modular Construction
It is indeed essential to have a working knowledge on modular construction for in depth understanding of the upcoming chapter. Some of the terms used in the modular construction process are listed below:

a) Specifying value from the customer’s perception.
b) Identifying the Value Stream.
c) Flow.
d) Pull.
e) Perfection (acceptable quality)

2.9.1 Specifying Value
Directed on practices that yield interim products that create up crucial blocks of the ending product, an accomplished ship is the procedure of identifying significance from the customer’s opinion [27]. By this effort, the panel block assemble procedure was designated as one of the critical practices someplace realistic analysis and enhancements can be done.
2.9.2 Identifying the Value Stream
A prerequisite to refining flow is the second principle of identifying the value stream. The value stream comprises all procedures included in the manufacturing process that generate added value [27]. The block manufacturing space begins with section fabrication and indications headed for accomplished blocks. It is essential to comprehend the procedure breakdown by isolating it through actions and examining how enhancements can be done. The block assembly process is break into nine key actions as shown below [8]:

1. Panel assembly,
2. Panel welding,
3. Panel layout,
4. Longitudinal fitting,
5. Longitudinal welding,
6. Internal structure fitting,
7. Welding and outfitting of built-up unit,
8. Turning and fitting,
9. Welding and outfitting

Figure 7: Panel-block assembly line. Sources: [8].

2.9.3 Flow
The third lean principle, flow, is identical significant since the development of interim products in shipbuilding. This is where what generates added value and whatever the consumer is agreeable to pay for. Refining flow involves the prevention or decrease of bunches and lines and formation of no stop flow. Similarly, non – value added activities throughout the manufacturing processes necessity be condensed and carried to a least. Added-value activities contain welding and outfitting, while non-value added activities comprises arrangements, install, waiting, storing, and extreme unnecessary fitting [27]. Remind that during buffer denote non-added value between activities in Figure 8 below, here is buffers in the interior the procedures themselves at the same time. An example, the panel line and block assembly procedures have interior buffers or no added significance actions that will moreover necessity to be condensed. It consists of coming up in the middle of the interior workspaces, and extreme arrangements and management [5]. Joining the panel line with block assembly reduces the transportation and coming up buffer among the two procedures and inevitably increases movement. The state-of-the-art method by modern world class shipyard is uniting the workspaces of the panel line and block assembly into single method which is called panel block line assembly. Furthermore to the removal of transference among the formerly isolated processes, the workspaces turn out to be additional rationally systematized and stability assemble sequence interval more competently that consequences in upgraded flow [5]. This is in agreement to trim quality that purposes to continuously retain sequence times amongst workspaces the identical.

Figure 8: Diagram of value added time and non – value added time
Source : [28]

2.9.4 Pull
Principle for deals with pull by which in the panel-block process indicates that the workspaces make in-between goods equally essential by request so that big clusters of blocks do not accumulate in the shipyard. As a result, it is in agreement to group technology which really revenues that interim products stay assembled in slight bunches as necessary by request as disparate to large batches that results in pointless storage and is dissimilar to lean principles [29].

2.9.5 Perfection (Acceptable Quality)
Lastly, principle 5 focuses on perfection or quality that is balancing to flow and generating added value, since if an interim product for case a double bottom block has flaws, then the flow is disturbed in line for to essential maintenances. As well, the added value of the compromised block is declined at the same time. Consequently, sustaining and refining upon quality helps constant flow and formation of added value interim products. It will focus on the third and fifth principle that consists of refining flow of interim products beside with preserving and refining quality at the same time, since the two principles are corresponding to each of it. The shipbuilding industry with various forms of manufacturing procedures and interim products shortages a precise method that will let organization and fabrication engineers to improve a program. This will increase the flow of the interim products though sustaining and/or cultivating quality together [27]. Increasing flow deprived of maintain quality would form larger complications than it resolves. It is for the reason that the interim manufactured products would require be fixing or revising. It shows that movement would essentially be dislocated and not upgraded and left-over would effect. For conclusion, the five lean principles are interconnected and it is impractical to purposely overlook any single of them although potential manufacturing complications starting from manufacturing point of view [5].
2.10 Modular construction shipbuilding in Malaysia

According to Malaysia Shipbuilding and Repair 2015 and 2016 [1] similar to other parts of the world, the Malaysian shipping industry had grieved amidst the worldwide downturn and performance declined in main shipping trades. As request for shipping service area flatten, SBSR industry players faced very challenging market conditions. Since 2010 until mid-2014, the Oil and Gas sector remnants fortunate after suffering a low cycle in 2008/2009 underpropped by high oil prices and major projects by local and international players. The O&G sector is one of the strongest driving powers 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, faster turnaround is the main reason especially to ship operators that are servicing the O&G sector. In Malaysian Development that focuses in 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 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 [30].

The shipbuilding industry of Malaysia is getting larger and ship builders 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 journey into modular building technique is also one of the feature that necessities to be strained on the shipbuilding technology. By having this, shipyards in Malaysia will have the competency and capability to commence to construct huge and intricate vessel [31].

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 more rapidly, more reasonable and environmentally-friendly, with all the identical architectural aesthetics that you would assume 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 9 [12] and Figure 10 [12]. 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 10 [12].

Other than that Royal Malaysian Navy also implemented this modular construction method which is this was proved by Royal Malaysian Navy project. According to the statement, three vessels will be built and assembled in South Korea starting from January 2018 while the rest will be block built in South Korea and assembled in Malaysia with South Korean shipyard Daewoo Shipbuilding & Marine Engineering Co Ltd (DSME) [32].

2.11 Limitation of Modular Construction Shipbuilding in Malaysia.

Multi-site construction may also involve possible disadvantages such as additional costs especially in Malaysian shipyard. First, the problems of accuracy control become more acute because the design and build tolerances must be maintained at several shipyards. Common nomenclature, techniques, and software packages must be used to ensure that the blocks built at different shipyards align correctly during assembly. Problems with alignment can lead to potential significant re-work costs. Blocks must be constructed or reinforced in a way to ensure that dimensional tolerances are maintained during transportation. They also may require additional bracing or structures for the transportation process, which will incur additional costs. Finally,
since processes must be coordinated among several shipyards, managing the schedule for construction and delivery of the blocks becomes more difficult. Delays in block construction at one shipyard, or delays in delivery caused by transportation problems, can seriously throw off the schedule for the delivery of the whole ship.

3.0 CONCLUSION

The objective of this paper is to critically review the modular construction status and development in Malaysian shipyard, as well as to study the acceptability of a known method, but yet are not fully practice in Malaysia.

The several factors that contribute to the development of the modular construction shipbuilding in Malaysia are the resources of material, eco-friendly construction awareness, latest development of technologies and expertise, which all this factors lead to the eco-sustainable industries. This method is a promising solution that reviewed by many experts, particularly when it involved a large and complex project.

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