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Egyptian Shipyard Partial Lean Manufacturing Implementation

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Abstract

Purpose: *This work tries to explain the notion of lean manufacturing as an engineering management strategy that can be used by Egyptian shipyards to assist them to compete in the global shipbuilding market.*

Design/Methodology/Approach: *Lean manufacturing uses tools like just-in-time, one-piece flow, and takt time, to improve product cycle times and quality by getting rid of waste in the manufacturing process. These tools are the foundation for eliminating waste in the shipbuilding industry. To help Egyptian shipyards to get a decision regarding how to respond to lean shipbuilding, this work gave a thorough overview of the potential applications of Lean Manufacturing Principles. It additionally improved the presentation of lean manufacturing in a manner suitable for Egyptian culture that is based mainly on the professionality of the workers not on robots, thus assisting the Egyptian shipbuilding sector to be closer to the principles of lean manufacturing.*

Findings: *By applying lean manufacturing tools in a block assembly line at the Egyptian shipyard, the greatest value of waste has been recognized. The shipbuilding cycle time for a 125-ton block assembly has been reduced from 60 days to 30 days as the workshops were capable to deliver two blocks in 60 days instead of 120 days, and the block production lead time was reduced to 50% of the original, reduction in the production lead time of block per man-hours to become 7100 instead of 9499 man-hours.*

Key-words:
Lean Thinking, Process Flow, Lean shipbuilding, Group Technology, just in Time.

INTRODUCTION

According to The Global and United States Shipbuilding Market Report & Forecast 2022-2028, the market will generate USD 61,628 million by 2025, up from USD 43,371 million in 2019, with a CAGR of 4.8% over the forecast period. The market is primarily driven by rising investments in marine infrastructure, rising trade volume, and rising demand for new ships and vessels. The market for bulk shipbuilding projects, which made up 34% of the total shipbuilding industry in 2019, is projected to grow to USD 61,628 million by 2025 from USD 43,371 million in 2019. Passenger ship building projects, purchased at a 36% rate, are projected to rise at a 4% annual pace to USD 80,700 million in 2025 from USD 51,400 million in 2019. Construction projects for cargo ships made up 34% of all projects, and by 2025, they are projected to reach USD 70,600 million, up from USD 51,400 million in 2019.

The phrase "lean manufacturing" first appeared in the 1990s, following the publication of the book "The Machine That Changed the World: The Story of Lean Production" (Womack et al., 1991). The movement of manufacturing concepts from professional worker-based production through mass production to lean production is continued in this book. Although lean manufacturing has its roots in the automotive sector and the Toyota Production System, other production lines are now using it. Lean manufacturing aims to decrease waste, boost efficiency and production, add value, lower costs, and boost competitiveness. Achieving consumer satisfaction is the main goal of lean shipbuilding.

Lean manufacturing, which was first developed inside the Toyota production system, is becoming more and more popular among manufacturers across all industries. It is not done by adding new methods to the way that products are made, but rather by altering the way that production is thought of. Although switching to lean shipbuilding could be challenging, the outcomes urge shipyards to try it. The fact that ships are build-to-order projects makes using lean manufacturing principles in the shipbuilding sector particularly challenging. Probably not all of Toyota's lean tool application techniques will apply to the shipbuilding industry, but the philosophy and principles can be applied with some adjustments. It is possible to observe a lot of the same principles used in the Toyota production system at work in shipyards by looking at models of world-class shipbuilding, for instance, Japanese shipyards use largely standardized modular designs with a steady flow of basic and intermediate parts, materials are precisely sequenced and moved through the shipyard utilizing the Just-in-Time principle. Instead of being examined, quality is built-in at the production station. Processes are timed and standardized using takt time. Instead of being transported into the stockyard months in advance, steel plates are brought in as needed. The main issue is that Egyptian shipyards have not yet entered the global market, preferring to supply the domestic commercial and military markets. Despite advancements in the field of standard and standardized production directed by intermediate products generated by the Egyptian shipbuilding industry, its overall integration level is still below the world-class level, nevertheless. Additionally, most Egyptian shipyards still employ the conventional intensive production management technique. The competitive advantage declines as labor expenses rise.

Egyptian shipyards must adapt their manufacturing processes and rely on lean manufacturing philosophies and practices because of steps taken to increase their competitiveness. The Toyota production system, the underlying lean concepts, and the best applications of the lean methodologies, according to the author, will serve as a platform for modernizing the production processes used in Egyptian shipyards.

This paper provides a framework for using the lean shipbuilding process ideas. within the assumption that the ship is built to be producible according to lean principles. The lean shipbuilding model will describe the lean manufacturing philosophy in the shipbuilding industry. Additionally, some outstanding shipbuilding examples will be provided.

Shipbuilders aim to increase productivity, cut labor costs, and shorten the production cycle if they want to remain in business and become more competitive (Liker, 2004). Utilizing lean manufacturing as an engineering management strategy, shipyards will have a competitive advantage. Eliminating waste is one of the objectives of this lean thinking, which can improve customer satisfaction and turn waste into value.

Traditional versus Lean Shipbuilding

Push vs. Pull

Lean shipbuilding is an engineering management approach that seeks to reduce waste and non-value-added operations throughout the shipbuilding process to improve output and quality, lower prices, and adhere to lead or delivery times.

Traditional shipbuilding uses the push technique to create numerous identical ship parts in a single run. Similar ship parts are produced one by one until the desired quantity is reached according to a precise schedule. This technique, which has a high degree of anticipation, may result in either overproduction or underproduction. Process items are moved back and forth between workstations during production. Parts and subassemblies stay idle during delays, where they can be lost or destroyed, this not only uses capital but also takes up space.

Lean shipbuilding uses the pull technique. No part is produced in a pull technique unless the customer demands it. The customer in this case could be anyone from the assembly welder to the owner of the vessel. The system is very sensitive and flexible to the needs of the consumer because this procedure is demand oriented. As soon as a part is finished, it is used, preventing downtime between workstations. There is no value added to the part by the downtime between workstations. Because the part is enhanced at each stage, the true value is added at the workstation. It becomes more useful to the customer with each development.

Delivery periods for raw materials are another distinction between push and pull techniques. During a push cycle, the material is ordered and delivered well in advance of the scheduled date. Large stocks of materials that may not be needed for some time result from this. Once more, unused materials result in increased expenses for both the land needed to keep them and the materials themselves, which are not regained until the materials are used. but during the pull cycle, smaller orders and deliveries are often made. A pull cycle can take delivery of small lots many times during the day, whereas a push cycle might take delivery of huge quantities of material once a week or once a month. Smaller lot sizes are ensured, as a result, as well as the storage spaces.

Batch and Queue vs. Continuous Flow

Large batch sizes are another type of waste that is present in conventional shipbuilding. A batch is a collection of parts that are created sequentially up to a predetermined number, at which point they are moved to the following station. The term for this is batch and queue flow, batch refers to the volume of a part produced, and queue refers to the parts' waiting period until they are required. The method determines the different batch sizes. Each part must wait until all other parts in its batch are finished before it can be released and sent as a batch to the next station. The part wastes time by being stored in a bin after being transferred to the following station until it is needed for manufacturing. The lead times for freshly ordered products are also lengthened by this batch method. Before the production line can be altered to accommodate new orders, a fixed number of batches must first be produced. This increases the time needed to implement a change order in addition to increasing the time needed to deliver a product to the client.

In lean shipbuilding continuous flow is used. Waiting time is eliminated by moving each part to the next station as it is created. Additionally, it enables the shipyard to deliver the appropriate part in the appropriate quantity at the appropriate time in response to customer demand. Since parts are only produced when needed, the manufacturing process can be modified to satisfy client demand.

By reducing the number of Defects through product inspection by the workforce at each station and reducing the damage that may happen while the product is waiting to be used, continuous flow also contributes to improving the quality of the finished product. The next operator can instantly see any flaw that can develop during continuous flow from the preceding process. After that, the process is stopped until the issue can be resolved, avoiding damaged parts from leaving the shop and raising overall quality.

One-piece / Continuous Flow

One-piece flow entails establishing assembly techniques for the creation of subassemblies, units, and part families that go through the same set of processes. Between 1965 and 1995, Japanese shipbuilders who adopted such lean techniques saw a 150 percent boost in productivity.

Hull divisions are first defined by planners, who then break them down into pieces or blocks, which are then further broken down into sub-blocks or subassemblies, and so on. The zoning procedures are finished by defining zones that can be produced in a single piece. One-piece construction is made easier along the manufacturing line by intricate detail design. Comprehensive subassembly integration for one-piece flow requires master scheduling execution.

Lean Shipbuilding Overview

Philosophy of Lean Shipbuilding

Because it utilizes less of everything than the mass production method, this system is known as the "lean manufacturing system." To build a new ship in half the time, lean manufacturing uses half the labor force in the facility, half the manufacturing area, half the tool investment, and half the engineering hours. Toyota's Production System is based on 14 principles under four sections, all beginning with the letter P. (Philosophy) Each organization must have a long-term philosophy. (Process) The right steps will produce the right outcomes. (People) By improving their work, they must bring value to the organization. (Problem-Solving) Regular problem-solving results in structured learning. Eliminating the Eight Waste Elements has become the core of lean shipbuilding.

Fig. 1. The 14 principles / 4P's model / lean shipbuilding

Lean Shipbuilding Five Principles

As per Figure 2, Lean shipbuilding's five principles are:

Fig. 2. Lean shipbuilding's five principles

I- Identify value to identify customer needs from Operations. This can be done using value management.
II- Map the value flow, processes required to define the Product as value flow, so mapping will help in Understanding.
III- Create a process flow to avoid or reduce batch and Queue, if possible.
IV-Establishing pull system, producing when and what Customer's needs.
V-Seek for perfection and continuous improvement.

Proceed to Lean Shipbuilding

When lean shipbuilding is used, the shipyard becomes a lean enterprise. According to Liker and Lamb (2002), shipyard management should do the following:

i- Construct the system, learn by doing, then train in an 80:20 rule (80% of outcomes comes from 20% of causes, to prioritize the 20% of factors that will produce the best results).
ii- Map the pilot value stream to demonstrate the resilience of the system and provide a benchmark example.
iii- Map the future-state value stream.
v-Teach in a kaizen (continuous improvement) workshop and implement quick adjustments.
vi-Sort value stream sample data to improve clarity.
vii-Making lean transformation imperative is necessary since it is not a voluntary process.
viii-Select lean leaders, hire a lean specialist, and engage the professionals.

Definition of Waste in Lean Shipbuilding

Numerous manufacturing processes present the possibility of waste issues impacting worker productivity, product quality, costs, and production time (Fitriadi et al, 2021). Waste in lean shipbuilding is anything that increases the time and expense required to build the ship but does not improve its value in the eyes of the customer. Value-added activities make the product a desirable item for the customer. Figure 1 shows simplified steps required to sub-assemble the ship hull steel plates. Only activities displayed in dark green add value. The light green dotted activities do not add value from the customer's point of view.

Since the value-added time makes up a small portion of the overall time limit, it is evident from Figure.1 that the overall benefit of cutting cycle time value-added activities is only up to a small portion of the time total. The efficiency of value-added activities may be attacked, as may be anticipated from mass productive thinking. One may, for instance, shorten the cycle time required to cut steel.

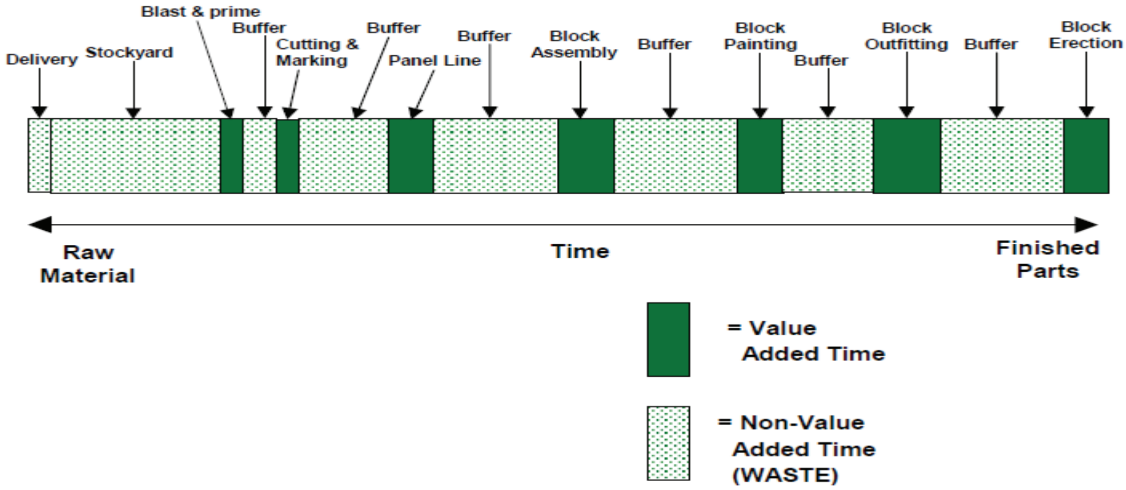

Fig. 3. Shipbuilding value-added / non-value-added activities

Value- added activities are activities that, in the owner's perspective, provide added value to a ship. This includes steel processing into subassembly and grand block assembly.

Non-value-added activities are activities that, from the owner's perspective, do not add value to the ship, for example moving sections from one station to another. Those activities include waste and must be minimized or eliminated.

Activities that do not add value to block assembly. But it needs to be done because if not done it will cause the supply process to be disrupted. Those activities include waste that is difficult to eliminate. For example, inspection activities, or waiting for machines.

Utilizing the Just-in-Time Method

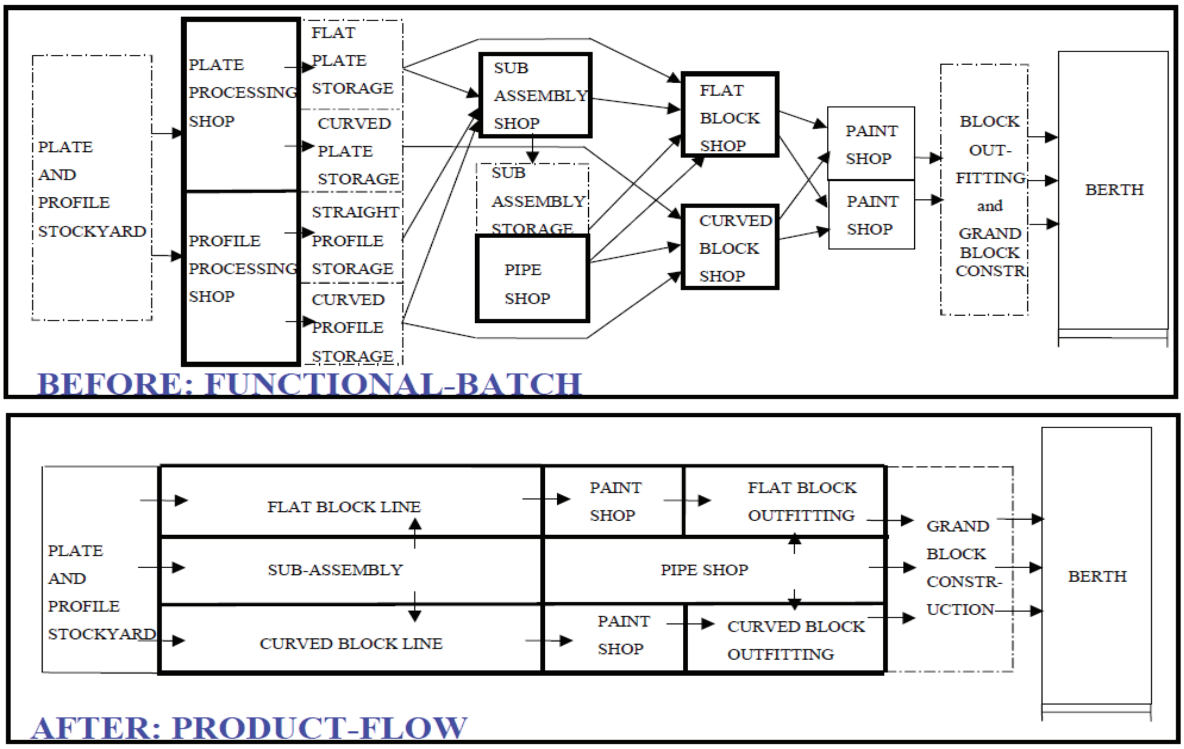

Fig. 4. Just-in-time in shipbuilding (Liker, 2002)

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By obtaining the proper number of raw materials and creating the proper quantity of goods at the proper location and time, the just-in-time manufacturing principle helps to eliminate waste (Phogat, 2013). A one-piece flow is perfect for an on-demand production system (Kolich et al., 2012). Although this method is primarily used for mass production, elite shipyards, particularly Japanese yards, have adapted it. Therefore, a one-piece flow, as seen at the bottom of Figure 1, is the best solution from the perspective of lean manufacturing. In this situation, one can work with one plate and one stiffener at a time and cut only the material he/she needs to pass it on, finish cutting, pass it on, complete the subassembly, pass it on, and assemble the block. An expanded view of the shipbuilding process is shown in Figure 1. Egyptian shipyards have often been arranged according to their functions. For instance, all buildings, whether curved or flat, are created in a single workshop, and both straight and curved profiles are created in different workshops. Panels and profiles are used to create large quantities, which are subsequently put into storage. After that, they are moved to the sub-assembly for sorting. Every component must go through the same paint shop, which frequently turns into a bottleneck. A typical configuration in Lean Shipyards is depicted in the bottom portion of Figure 1. The yard is set up according to the "product line" in this instance.

In this scenario, flat blocks go through one set of operations, and curved blocks go through another set of operations, making up a manufacturing line rather than separate vessels. For instance, all flat panels are cut in straight profile process lanes before being delivered in tiny batches to the flat block line for assembly. One paint shop is designated for flat blocks, and the other is designated for curved blocks, as shown in Figure 1. After being prepared in separate locations, flat and curved blocks are then brought together to form a huge block assembly.

Use of Takt Time Technique

Takt time, a pacing mechanism used in lean shipbuilding operations, is introduced to help control the production flow. Takt time is primarily defined by the "Customer Demand Rate."

The ability to give shorter lead times to clients and enhance the usage of the shipyard, which results in increased revenue, is one of the major advantages of continuous-flow manufacturing. Depending on the size and complexity of the ship, Takt time might differ significantly from ship to ship. Similarly, each portion of a ship, which is made up of numerous distinctive components, may have a varied Takt time. It makes more sense to think of the ship as a collection of smaller pieces when considering Takt's period.

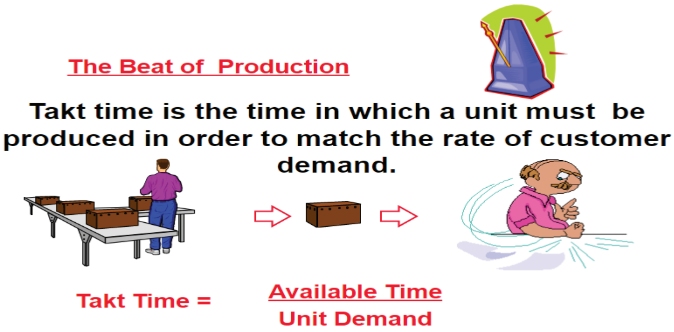

Fig. 5. TAKT TIME (Liker, 2002)

Utilize the Group Technology Approach.

A concept known as "Group Technology" is founded on the idea that related products should be handled similarly. Group Technology shortens the lead time for production, work-in-process, labor, tooling, rework, scrap material, setup, delivery, and documentation (Shahin, and Janatyan, 2010). The conceptual model for Group Technology is divided into four parts:

i- processes: product groups, classification, design conformity, group production, group technology management, and the automated factory system.
ii- Intermediate variables: determining the part family, standardizing the process plan, group scheduling, group tooling setup, reducing the number of materials purchased, using computer-aided design and manufacturing, and using CNC machines.
iii- Production wastes: operating power, inventory, movement, complexity, waiting, needless process, and defect.
iv-Objectives: The major goal is to lower waste and expenses to increase production.

Employing a Simulation Model

The expense of finding optimal solutions and the risk associated with making poor decisions in the real world can both be significantly lowered by using a virtual shipbuilding environment (Krause et.al, 2004). The procedures are as follows:

i- Setting goals as simulations can be used for multiple goals, increasing productivity, assisting in new investments, reducing inventory, material flow analysis, manpower sizing, and continuous improvement of production.
ii- Collecting the appropriate data.
iii- Building the model and establishing the logic and procedures to represent the real system.

iv- Validating the form to check that the model is already working as a real system.
v- Running the simulation and collecting the results, if one must, change some parameters and see how the model behaves, otherwise, he/she will fall then back to step (iii).
vi- Analyzing the results to aid decision-making.
vii- extracting Final documentation with a detailed description of what needs to be done.

European Shipyard Using Lean Manufacturing (Kolich et al., 2012)

The actual lean manufacturing implementation requires the transformation of traditional panel lines and built-up panel lines which still exist in many European shipyards. Combination of lean principles results in time savings and in man/hour reduction, which directly brings significant savings to the shipyard (Kolich, 2011). Table 1 below shows the activities of the traditional block assembly lines that exist in most European shipyards.

Table 1: Activities of the Block Assembly Workstations (Kolich et al., 2012)

station	description	Takt time (hours)	Coefficient	Takt time x Coeff. Man/hours
1	Forming a panel by joining and welding steel plates	4	4 seams x 2 workers x 4 panels = 32	128
2	Turn over the panel to weld it on the other side	4	4 panels x 2 workers = 8	32
3	Marking the plate for longitudinal stiffeners	4	4 panels x 2 workers = 8	32
4	Fitting and welding of longitudinals	4	4 panels x 2 workers = 8	32
5	Quality control and transportation to the built-up panel line	4	4 panels x 1 workers = 4	16
6	leveling with heat	8	2 built-up panels x 2 workers =4	32
7	Labeling, laying, and tack-welding of transverses	8	2 built-up panels x 12 workers = 24	192
8	Welding of transverses and cleaning the weld	8	2 built-up panels x 12 workers = 24	192
9	Grinding and preliminary outfitting	8	2 built-up panels x 10 workers = 20	160
10	Final block assembly before erection on the slipway	16	11 workers	176
Total man/hours for complete double-bottom block assembly				1000

Lean manufacturing when implemented properly lead to a decrease in both duration time and man-hours as well as in a decrease of necessary space in the shipyard. However, pieces of equipment are recommended to be installed in a block assembly line, Figure 6 shows the workstations:

i- At lean workstation 2, install a high-grade fitting machine to do fitting up to four longitudinals simultaneously,
ii- At workstation 3, install four automatic welding machines on the girder to weld longitudinals on both sides simultaneously,
iii- At workstation 4, install three machines of one side automatic Flux-Copper Backing,
iv- At lean workstation 5, install Push-type insert equipment to push transverses,
v- At lean workstation 6, install four portable welding robots, suspended from two girders.

By conducting the elimination of the non-added value activities, where the transverses have cut-outs that require additional work for the fitting and welding of lugs. So, when lean is applied, the panel-

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block assembly line eliminated the need for lugs, as specified in Figure 7.

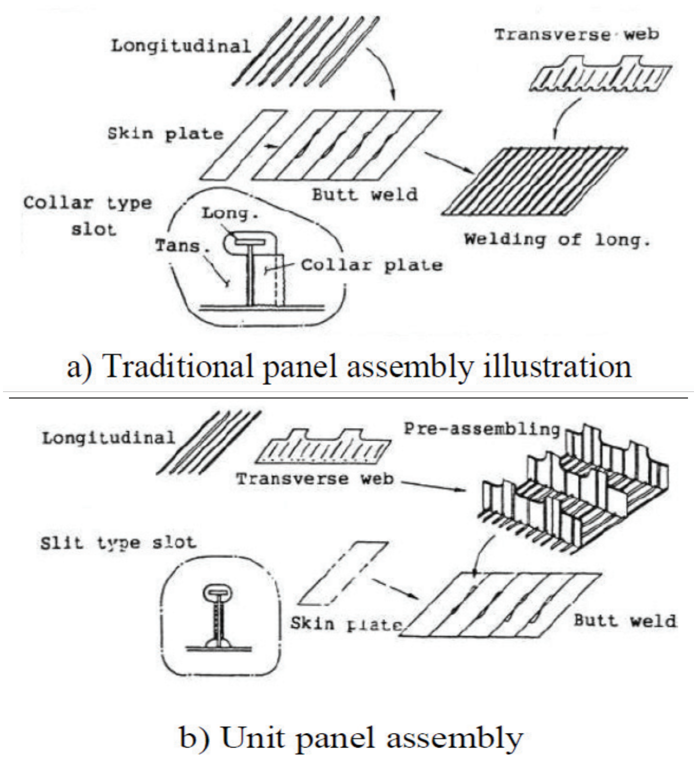

Fig. 7. The traditional vs. lean panel line (Kolić, 2011)

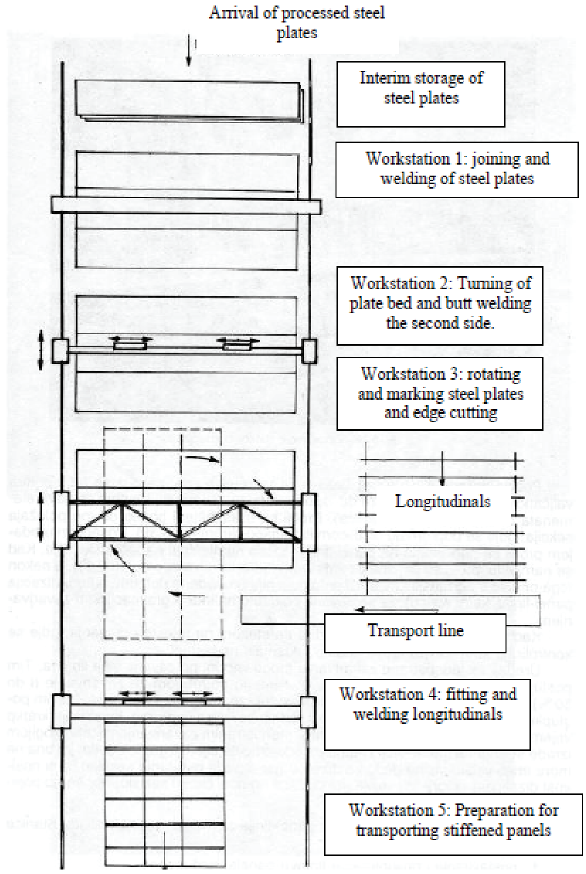

Fig. 6. Panel line workstations (Kolić, 2011)

Table 2 below shows the activities of the lean block assembly workstations.

Table 2. Activities of the Lean Block Assembly Workstations (Kolich et al., 2012)

station	description	Takt time (hours)	Coefficient	Takt time x Coeff. Man/hours
1	Unit plate trimming along the edges	1	5-unit plates x 4 panels x 2workers = 40	40
2	Turn over the panel to weld it on the other side	1	5-unit plates x 4 panels x 2workers = 40	40
3	Marking the plate for longitudinal stiffeners	1	5-unit plates x 4 panels x 2workers = 40	40
4	Fitting and welding oflongitudinals	1	4 one-sided seams x 4 panels x2 work-ers = 32	32
5	Quality control and transportation to the built-up panel line	4	2 built-up panels x 20 workers = 40	160
6	leveling with heat	4	2 built-up panels x 5 workers = 10	40
7	Labeling, laying, and tackwelding of transverses	4	12 workers	48
Total man/hours for complete double-bottom block assembly				400

Egyptian Shipyard Under Study to Adapt to Lean Shipbuilding

The Egyptian shipyard under study is a medium to big size shipyard. It produces a variety of vessels, including river barges, tankers, ro-ro ships, and medium-sized warships. Additionally, it has the capacity to produce 35 boats every year. Two slipways, one with a 300-ton lifting capacity overhead gantry crane, are used to launch ships. According to the capacity of the cranes at the workshops and the capacity of the carriers, the erection blocks are planned to be close to 125 tons. Although this shipyard has decent production facilities that meet the needs of the productive product mix program, it is necessary to be improved to increase competitiveness. The best workshop to apply the lean method as a pilot form within the shipyard is Assembly & Welding Shop and Block assembly shop. A lot of waste has been recognized in this workshop.

Cutting and Welding Facilities at Egyptian Shipyard (Krishnan, 2012)

i- Metal Processing Shop, where automated Plate Cutting Machines, shearing machines, Hydraulic Presses, and rollers capable to do Marking, Cutting, and Forming metals (steel, stainless steel, and aluminum), are attached to the Metal Processing shop a stockyard for Plates and Sections.

ii- Unit Assembly & Welding Shop consists of four lanes; the first is for assembly and welding of the flat section, and the second is for the assembly and automatic submerged arc welding at the entrance of the lane. Third is where small sections /units of stiffened floors and girders, built-up web frames, and deck beams are assembled and welded using mainly semi-automatic CO_2. Last is where the slightly curved and framed sections /units are assembled and welded using mainly semi-automatic CO_2. It is normal that all the units/sections be inspected by the QC staff attending permanently the workshop and any NDT is to be applied to all built sections prior to being transported to the block assembly workshop.

iii- Block Assembly and Welding Shop, where Blocks up to 125 tons are assembled out of the subsections and sections supplied by the unit assembly and welding shop using the various types of processes of welding on the flat stand or curved stand depending on the specified block, quality took place for approval then transported using transporters to Blast and Painting Shop and then to the slipway.

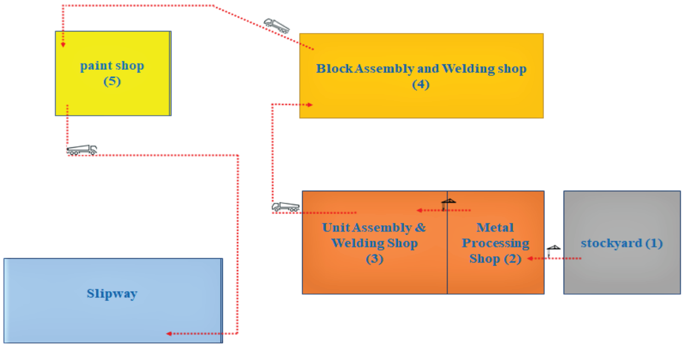

Fig. 8. Shipyard production system before lean implementation

Egyptian Shipyard Production System

The shipyard production system did not cope with the lean concept. In the past times, the steel plates were pushed from the stockyard (1) to the Metal Processing Shop (2) to be cut and marked according to the shop drawings. Then pushed to the Unit Assembly & Welding Shop (3) to get an assembly of micro panels and panels up to the small section, then the small sections are loaded onto the transporters and taken to the Block Assembly & Welding shop (4), then the blocks are loaded onto the transporters to the paint shop (5) then pushed to the slipway to assemble all blocks together on keel laid at the slipway (see Figure 2) below.

Egyptian Shipyard Production Line Wastes

Table 3: Observed Wastes at an Egyptian Shipyard

According to Toyota classification	Observation
Waiting	Wasted time because of the lack of operating procedures and searching for raw materials.
Over-processing	Lack of standardized work. Lack of logical sequence of tasks. Lack of tasks organization.
Unnecessary motion	Unnecessary movements between stations and searching for components.
Defects	Long Stiffeners were cut and deformed during transportation to the next station due to a lack of organization and coordination.
Inventory	Out of stock of some parts and exceed of other parts due to lack of organization.

Transportation	Unnecessary transportation of sections to be assembled at the next workshop.
Overproduction	Cutting More panel profiles before it is required
misallocated personnel	Non-utilized workers or assigned for a job not fitted with their talents.

MEHODOLOGY

Change Process Sequence of the Block Assembly Line (Kolich et al., 2017), (Oliveira 2018) The target was to enter the stages of lean manufacturing without any additional financial burdens on the management achieving a clear result that encourages moving forward toward the implementation of lean manufacturing. It was by searching for the greatest value of waste in production processes and finding that there was a transportation process that did not add value to the final product, which is the transfer from the Unit Assembly & Welding Shop (3) to the Block Assembly & Welding shop (4). This step was canceled, and part of the Unit Assembly & Welding Shop (3) was re-equipped to become an additional Block Assembly and Welding shop (*4) with Shop (4), also equip the Block Assembly and Welding Shop (4) to perform as the processes of the Unit Assembly & Welding Shop (3) to be (*3).

The new sequence of production became; the steel plates are pushed from the stockyard (1) to the Metal Processing Shop (2) to be cut and marked according to the shop drawings. Then pushed to the Unit Assembly & Welding Shops (3) & (*3) to be assembled into small sections, then the small sections are assembled to form the block, in the Block Assembly Shops (4) & (*4), The blocks are then loaded onto a transporter to the Blast & Painting Shop (5), then pushed to the slipway to assemble all blocks together (see Figure.3 below).

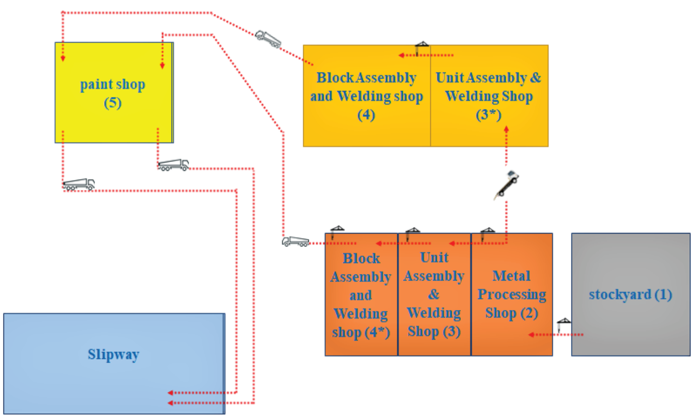

Fig. 9. Shipyard production system after lean implementation

RESULTS AND DISCUSSION

Using a lean shipbuilding system presented in this work to eliminate wastes, in this situation it came from transportation, which has an impact on ship production cycle time and delivery time.

Also, there is a hidden waste no one inside the shipyard notice which is misallocated manpower and misassigned areas. As Unit Assembly & Welding Shop was split into shop (3) & shop (*4) (doing the role of Block Assembly Shop), and the Block Assembly Shop is split also into shop (4) & shop (*3) (doing the role of Unit Assembly & Welding Shop), with surprising that both workshops are working perfectly at the same time with no additional manpower needed. Table 3 shows the comparison of the shipyard's production situation before and after the implementation of lean shipbuilding.

The traditional system for the Egyptian shipyard was designed to produce block assembly weighing 125 tons each using 12 m (length) x 3 m (width) steel plates with a thickness of 8 mm - the weight of the plate is about 2.2 tons, which means that the block uses 56.8 steel plates. Processing for only one plate takes 140 man-hours, and 7952 man-hours to produce one block assembly. i.e., there are about 1547 man/hours out of 9499 man/hours not assigned to work.

When partially implementing the lean tools in the Egyptian Shipyard, the shipyard has now two block assembly lines that are capable to deliver two blocks in 60 days instead of 120 days as in the traditional system.

Block production man-hour was reduced from 140 man-hours to 125 man-hours by canceling transportation activity from workshop (3) to workshop (4).

Production cycle takes 7100 man/hour to produce one block i.e., there are about 2399 man/hours out of 9499 man/hours not assigned to work. This is what gave the Egyptian shipyard the privilege of establishing a new block assembly line to be in parallel.

Table 4: The Comparison of the Shipyard's Production Situation Presented by the Egyptian Shipyard

Trade	Max capacity Monthly Man/Hour	Traditional	Lean implementation	
		Block assembly line Man/Hour	Block Assembly 1 Man/hour	Block Assembly 2 Man/hour
Metal Processing Shop				
Metal Processing Shop: Production Capacity Per Month: 210 Tons, The Number of Hours (40) Based on The Use of Steel Plate 12 Meters X 3 Meters with a Thickness of 8 mm - Weight of the plate is 2.2 Tons. The total capacity monthly is 3818 Man/hour.				
Cutting & Marking	2290	20	15	15
Grinding	764	10	10	10
Steel Forming	764	10	10	10
Total	3818	40	35	35
Unit Assembly & Welding Shop				
Unit Assembly & Welding Shop: Production Capacity Per Month: 130 Tons, The Number of Hours (50) Based on The Use of Steel Plate 12 Meters X 3 Meters with a Thickness of 8 mm - Weight of the plate is 2.2 Tons. The total capacity monthly is 2954 Man/hours.				
Assembly & Welding	1181	20	15	15
Final Welding	1477	25	20	20
Additional Marking	148	2.5	2.5	2.5
Straightening	148	2.5	2.5	2.5
Total	2954	50	40	40
Block Assembly and Welding shop				
Block Assembly & Welding Shop: Production Capacity Per Month: 120 Tons, The Number of Hours (50) Based on The Use of Steel Plate 12 Meters X 3 Meters with a Thickness of 8 mm - Weight of the plate is 2.2 Tons. The total capacity monthly is 2727 Man/hour.				
Assembly & Welding	1090	20	20	20
Final Welding	1365	25	25	25
Additional Marking	136	2.5	2.5	2.5
Straightening	136	2.5	2.5	2.5
Total	2727	50	50	50
Total Line Man/hours		140	125	125
Total Man/hours	9499	7952	7100	7100

CONCLUSIONS

The Egyptian Shipbuilding industry needs changes to become competitive in the international shipbuilding market. Lean manufacturing as an Engineering Management approach when implemented properly at the Egyptian shipyard will do the best arrangement of the shipbuilding processes. Lean shipbuilding is characterized by low cost, small investment, and great benefits compared with automation. That is what encouraged Egyptian shipyards to try to transform to lean to benefit from the decrease in both duration time and man/hours as well as in a decrease of necessary space in the shipyard. lean shipbuilding that has been introduced in this work integrates lean some shipbuilding tools, such as just-in-time, takt time, and continuous flow operation. Also, identify the added and non-add value activities in the production process and recognize most of the wastes. The production efficiency of the Egyptian shipyard block assembly line was partially improved, the production balance was improved and identified, and personnel and time waste were reduced distinctly by using the lean shipbuilding introduced partially in this work. The shipbuilding cycle time for a 125-ton block assembly has been reduced from 60 days to 30 days as the shops became capable to deliver two blocks in the same 60 days instead of 120 days, and the block production lead time was reduced to 50% of the original, 25% reduction in the man/hour needed for block production.

Egyptian shipyard was able to open the 2nd block assembly line with no need for hiring more workers. According to cultural differences, this work is limited to Egyptian shipbuilding projects and Egyptian shipyards.

Now, the Egyptian shipyard has the available tool to step-by-step implement lean production and overcome the shortcomings of the traditional system that only focuses on plan scheduling and monitoring of the production process. although what has been achieved in reducing the production time by implementing lean shipbuilding in the Egyptian shipyard, but comparing to the European model, there are still many procedures required to be implemented to reach a competitive delivery time and competitive product price.

FUTURE WORKS

Logistics analysis, time analysis, cost analysis, and activity analysis in the lean shipbuilding system will be investigated (Leal et al., 2017). Moreover, the Egyptian shipbuilding operation process will be further optimized using discrete event simulation, while shell, outfitting, coating integration operation methods, and the layout of logistics facilities will be continuously improved to increase the production efficiency of shipbuilding and enhance the competitiveness of small and medium-sized shipyards.

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