4 IMPLEMENTING LEAN IN THE DESIGN PROCESSES — VALIDATION USING PHYSICAL SIMULATION

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Lean Manufacturing is a powerful philosophy, which advocates minimization of waste throughout the value stream both within the organization and outside in the supply chain. Majority of shipbuilders in United States have adopted the Lean Manufacturing philosophy to reduce cost and increase efficiency. However, attaining the goal of becoming a lean enterprise is still a utopia for majority of shipyards. Implementing lean principles in all facets of an organization's activity can only create a true lean enterprise. For many industries, the design process often constitutes a critical link in product realization process. Streamlining this process can result in improved flow in the value stream and reduction of the overall lead-time. This simulation tool was developed under a grant from NSRP, and in partnership with Old Dominion University, Northrop Grumman Newport News and South Tidewater Association of Ship Repairers. Results of lean implementation show dramatic reduction in lead-time for the design process.

Keywords: Design Process, Lean Implementation, Simulation Based Training Program, Physical Simulation.

1. INTRODUCTION

The basic purpose of the engineering profession is to develop technical devices, services and systems for the use and benefit of society. The engineering design process forms a link between the available resources and the requirements.[1] Design represents an answer to a problem, which has visible form, shape and function. In a broad context, design is, in fact, any purposeful, thought-out activity. Designing a product involves a constant decision-making process that includes problem solving in a sequential manner and analysis of constraints at each step.[2]

This paper, studies the generic design process utilized in the shipbuilding industry starting with the customer requirements to the final design. Critical problems in the design process are identified and appropriate lean tools are implemented to streamline the design value stream. The results are validated through physical simulation with groups of participants. The results from the simulation activity show the benefits of lean implementation. Results indicate that Lean implementation within the design process can result in reduced lead time and cost for an organization.

1.1. Literature Review

The design process is complex and plays a crucial role in the entire process from the concept to the point where the product is launched. It involves large number of people, space, paper work, time and eventually money. It is of prime importance that the product design is precise at the very beginning. Product design generally accounts for 5% of a product's total cost, but it affirms 75% of the product's total manufacturing cost.[3]

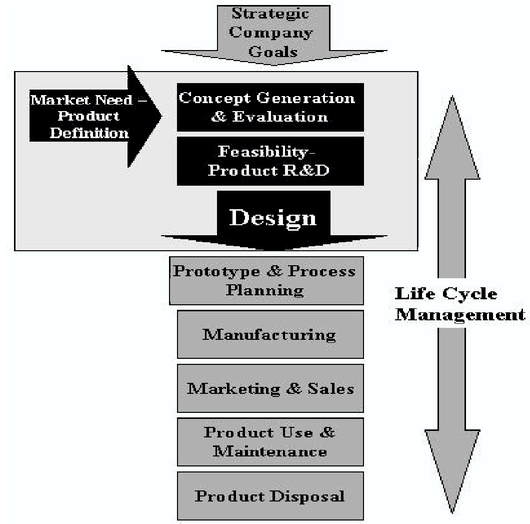

Figure 1. Product Realization Process.

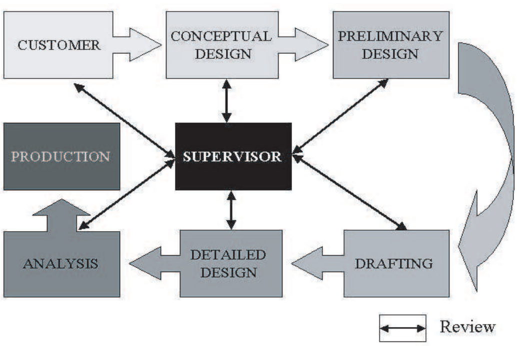

Figure 2. The Design Process.

Figure 1 shows the different stages of a typical product life cycle and the product realization process. First, it is initiated by the market need. It starts with the task of planning a product based on strategic goals of an organization and goes through stages of feasibility analysis, research and development, design and prototyping, market testing, commercial manufacturing, marketing, product use, maintenance and disposal.[1] We shall concentrate on the market need, concept generation and the feasibility analysis of the design.

A generic design process in shipbuilding is as shown in Figure 2. The process begins with the customer requirements, which are carefully transformed into specifications by the shipbuilders. The conceptual design department prepares preliminary dimensions of the ship i.e. length, beam and depth, based upon customer requirements. These dimensions are calculated by using a set of graphs, charts and rules of thumb. This is later refined through iterations. The output of conceptual design department is the input to the preliminary design department, which is responsible for calculating the power needed and the full load displacement of the ship. The drafting department prepares the preliminary CAD drawings of the ship. The detailed design department is involved in the inboard design and calculations like crew cabins, captains cabin etc. The analysis department carries out the stress analysis and the finite element analysis to make sure the design is safe under varying conditions of load. This design finally goes to the production department, where the ship is constructed in modules. These modules along with a few components and parts are assembled later at the dry dock by the water front services and various trades.

There are a number of iterations and reviews involved in each department. These iterations result in the refined and robust design of the ship.

As stated earlier, this research work is specific to the design process and hence will not focus on the production process or the work done at dry dock. Simulation development in other areas has been presented in the final report for NSRP.[4]

2. CRITICAL ISSUES IN SHIPBUILDING INDUSTRY

The process of lean implementation begins with the identification of waste through the value stream mapping process. Non-value added activities are present, in each of these departments. They are prominent in some, while less in others, but are surely present. These activities can be segregated into three distinct groups i.e. value adding, non-value adding and necessary non-value adding activities. 'Value Stream Mapping' (VSM) sets the guidelines for this task and hence forms the first step in this process. In VSM we literally map the entire process along with all the departments and cubicles. The exact flow of each document is mapped including the process time idle time and blocked time. There are two ways of tracking a document; either mark a document and follow it from the initial stage through the process till the results are obtained or go back from where the results were obtained, asking questions like where did this come from? Why did it come here? How long did it stay here? And so on. The 'Five whys' prove imperative in this process, wherein you start with one question and keep on logically questioning the answer five times.[5] This gives us a clear picture of which activity was value adding, necessary non-value adding and non-value adding, and accordingly we can take steps to improve the process.

The critical issues were identified through this process and through interviews of designers in the shipbuilding industry and they are:

1. Lack of communication
2. Multiple Review/Unnecessary Review
3. Lack of Standardization
4. Batch Flow
5. Functional Layout
6. Bottlenecks
7. The "Over the Wall" phenomenon
8. Long Lead Time

3. LEAN TOOLS TO ADDRESS THESE ISSUES

'*Lean*' is a Japanese philosophy, which aims at eliminating the non-value added activities to reduce waste.[6,7] Initially, industry focused on increasing the "value-added" activities on a product or process and often overlooked the non-value adding activities. But, due to high level of automation and superior manufacturing methods, there is little advancement that can be made towards increasing the value-added activities. Lean brought in an evolution by concentrating on the non value-adding activities, better know as 'muda' or waste, which almost account for more than 50%, for any process. Lean is about bringing a cultural change in the work force of an enterprise, to eliminate muda and to substantially increase the efficiency.[8] It also implies on the commitment of the management towards making an enterprise lean.

Figure 3 shows the house of lean.[9] The doorsteps are through value stream mapping wherein you identify the non-value adding activities. After deciding on these, with the support of a set of lean tools, we eliminate these activities. These lean tools form the building blocks of this house. The roof of the house represents continuous improvement, better known as 'Kaizen', wherein we prevent the waste from entering the house again.

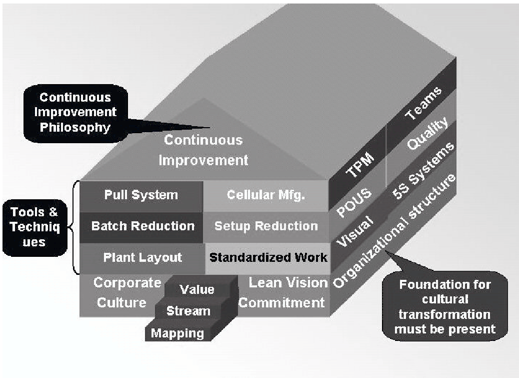

Figure 3. The House of Lean.

3.1. Co-location

'*Co-location*' increases the effectiveness of communication. People from various departments should be brought together and co-located to form a closed cell (analogous to 'cellular manufacturing' on shop floor). This way they can communicate with each other and share all the information and problems easily and directly.

3.2. Quality at Source

While defects in a physical product result in scrap and rework, and harm the company's image, similarly design flaws result in either reviews and rework or eventually a defective product. Multiple reviews may be required to keep a check on the quality, which result in longer lead times for the design process. Reviews are functional only if they add value to the process, i.e. optimize the results or process and not just spot the error. Reviews can be reduced to a certain extent by implementing 'Quality at Source', wherein the work is done right the first time. This minimizes the need for supervision and reviews.

3.3. Standardization

In the engineering design process, different departments and subcontractors may use different units e.g. inches, feet, meter etc for measurement of length or newtons, pounds, tons etc for the measurement of weight. 'Standardization' is an important lean tool to reduce the waste of time in conversion of units and reduce errors due to multiple units. In addition, production department may use different units than the design department. This may lead to confusion and possible errors. A standard unit must be used throughout, for a smooth design cycle, starting from conceptual stage to the end of production. Standardization also facilitates 'Interchangeability' which permits ease of business between two companies.

3.4. Single Piece Flow

Batch flow is another problem in the design process wherein a group of documents are forwarded to the next location. Typically in a shipyard, Friday would be the dead line to submit all the results and reports. Many a times, all the reports and results pile up during the week and then it is difficult to get things going at the last moment. 'Single piece flow' should be implemented in the engineering design process wherein people submit a single independent result or report as soon as it is done, and not wait for remaining documents. This also avoids bottlenecks and keeps the process balanced.

3.5. Line Balancing/Takt Time

'*Line balancing*' can be done in the department by forming cross-functional teams, in which people can perform multiple tasks. This way, the department starts working as a team and as soon as people are done with their work, they go and assist others who are still working. This would surely help synchronizing the flow, and also reducing the lead-time. Also, equal distribution of work among people in a department gives a balanced flow. The visual controls assist in uniform allocation of work.

"Takt" is the German word for the baton that an orchestra conductor uses to regulate the speed, beat or timing.[10] The customer's demand rate establishes Takt Time. It is the ratio of demand and available time.

3.6. Visual Controls

Visual Controls are an effective tool for making problems visible. When the problems are visible, the resolution can be found easily. Several techniques can be used for making problems visible. The workload at a station can be made visible by placing work orders so they can be seen by all. This makes the identification of bottlenecks easier by the supervisor. Also, cubicles in the office can be made of transparent glass or fiber so that a check could be kept at each workplace. This way, work could be distributed evenly to reduce holdups.

3.7. Integrated Product and Process Design

A good solution is to form 'cross functional teams' which work concurrently. This is possible by bringing the people from the shop floor, sales, design, maintenance and even the customer to actively participate in the engineering design process during the early stages. This forms the Integrated Product and Process Development team (IPPD). Here, people from various departments meet and collectively take a decision, so that future complexities can be avoided. By doing so, every department has a say in the product development, which streamlines the entire product cycle. This also prevents 'over the wall' phenomenon, where the design department prepares the drawing and specifications for various parts and submits it for production. This way, any problem with the product design, specifications or manufacturability, is noticed later in the process and then increases the cost due to rework.

3.8. 5S System

'5S' is a workplace organization system that must be implemented in every department. The five S's stand for; Sort, Set, Shine, Standardize and Sustain. In the engineering department where a lot of paper work is involved, 5S plays an important role, because it reduces clutter and provides for quick retrieval of files and folders. It also reduces the possibility of lost data and files and time spent in trying to find them. Also, 5S could be implemented in each of the personal computers that the designers use, so that all the data is well organized and stored systematically. Another aspect of implementing 5S is easy access to the data. By forming multi-functional teams we allow people to share their work. 5S enhances the sharing process because all the data is stored in a typical way for other team members to use it.

4. DESIGN AND DEVELOPMENT OF SIMULATION ACTIVITY

Simulation-based learning involves the placement of a student into a realistic scenario or situation. The student is then responsible for any changes that occur as a result of their decisions.[11] A simulation activity is a set of techniques and technologies to create guided, interactive, and often immersive activities that re-create experiences of a real-world environment. These are used to amplify or replace actual experiences. The nature of simulations consequently has a direct and immediate impact on learning, and performance improvement.[12–14]

The goal of the simulation activity is to design a container ship. Approximately 15 participants are required to form the design team for the simulation. The simulation is carried out in three phases,

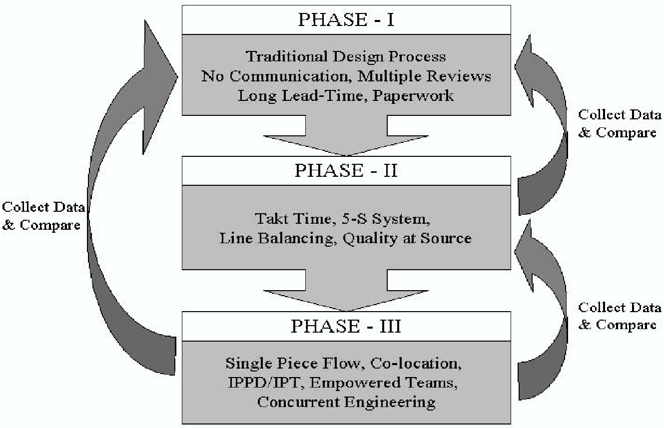

Figure 4. Structure of Simulation Activity.

Table 1. Performance Metrics.

PERFORMANCE CRITERIA	Phase I	Phase II	Phase III
Total # of Employees	14	14	13
Lead Time (to complete one order)	52	34	16
Cycle Time			
Customer Order	0:15	0:15	0:15
Conceptual Design	4:30	3:00	3:00
Preliminary Design	16:00	11:00	9:00
Drafting	3:00	2:00	2:00
Detailed Design	9:00	8:00	7:00
Analysis	10:00	8:00	4:00
Supervisor	9:00	2:00	2:00
Number of Reviews	5	2	2
Trips made by the Transporter	12	7	0
Paper Work- # of files forwarded to next Dept.	6	2	ERP
Cycle Time	**Phase I**	**Phase II**	**Phase III**
Preliminary Design #1	3:30	3:30	4:30
Preliminary Design #2	4:00	5:00	6:00
Preliminary Design #3	7:00	6:00	8:00
Preliminary Design #4	3:00	3:00	9:00

first being the traditional phases demonstrating the current state of design. Suitable lean tools are implemented in the later phases to increase the efficiency of the process. Figure 4 shows the structure of the simulation activity. The results from each phase are compared with the previous phase to see the improvements.

5. PILOT TESTING AND RESULTS

The pilot tests were conducted with the apprentices from NGNN along with a few graduate students from the Old Dominion University. The results for the simulation activity are shown in Table 1.

The total number of employees remains same through all the phases. The lead-time in the table is in minutes. The lead-time was reduced by over 70%, number of reviews was reduced by 60% and the transportation waste (man and material) was completely eliminated over the consecutive phases.

The room layouts for the three phases are shown below along with the lean tools utilized in each phase.

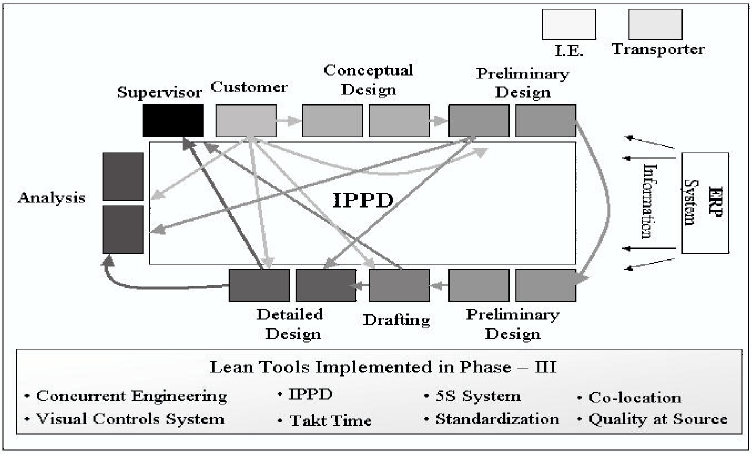

Figure 5. Room Layout — Phase III.

5.1. Phase–I

Phase I is the traditional phase. It comprises of long lead-time, multiple reviews, large number of paper work, transportation of man and material.

5.2. Phase–II

A set of lean tools is utilized in Phase II to reduce waste. Quality at Source is implemented to reduce the number of reviews, 5S is implemented to reduce transportation of documents and eliminate clutter and Line Balancing is done to eliminate bottlenecks.

5.3. Phase–III

Another set of lean tools is utilized in Phase III to complement the tools used earlier and to increase the efficiency. First, all departments are brought together by co-locating them. IPPD is a major breakthrough in this phase along with Concurrent Engineering. Visual Controls are used to improve the process. An ERP system may help synchronize all processes.

6. SUMMARY

This paper provides an overview of the engineering design process. It examines the current practices employed in the design process in the shipbuilding industry and provides a resolution to reduce the non-value added activities. Elimination of these non-value added activities from both on the shop-floor and above-the-shop-floor activities, ultimately lead to a lean enterprise. Among the above-shop-floor activities design and product realization process are an important part. The results from the simulation activity demonstrate that lean implementation can have a substantial impact on productivity.

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