Examining the Viability of Lean Manufacturing in Different Plant Environments

(STS & Technical Paper)

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

I. Introduction

Manufacturing engineering is the field that drives America's industrial sector through the improvement of manufacturing processes and plant operations. The foundations of this field were established in the early 20th century by Henry Ford, who implemented the assembly line for his Model T automobile factory, changing the operation from a cumbersome construction project, where batches of parts were independently assembled, to an organism that promoted the movement of parts through a set of standard procedures. This concept was further developed by Taiichi Ohno, an engineer for Toyota, who, not long after, sought to systematically eliminate all waste associated with the traditional assembly line (History, 2009). These efforts have given rise to the concept of Lean, which is a process strategy employed by many manufacturing companies, such as John Deere, Ford, Nissan, and Nike (Adams, 2022). There are five foundational elements to implementing Lean manufacturing: identifying value, mapping value streams, establishing flow, creating pull, and continuous improvement (Gomez, 2019). The only valuable processes are those which directly contribute to the needs of a customer. Before any changes are made to plant operations, the customers' needs must first be accounted for to ensure efficient productivity by eliminating sources of waste. Afterwards, the value stream of a plant must be mapped by visualizing how product flows from one stage to another, where specifically it flows, and how much time is spent at each stage. The resulting sufficient location and temporal data allows manufacturing engineers to discern the points of waste generation, such as waiting time, overproduction, and excess storage. Removal of this waste establishes or enhances flow by minimizing the time spent on frivolous activity. A pull system is also created, where production movement and plant output occur according to the specific demands of the customer instead of inventory accumulation driving the plant's output. The final step of continuous improvement allows manufacturing engineers and Lean practitioners to develop and implement preemptive designs that improve a given system's reliability, rather than hastily responding to system failure. In this Prospectus, I will detail the problem that Lean seeks to address and some specific ways this methodology is executed along with a revisitation of Lean manufacturing from a Science, Technology, and Society (STS) perspective. I will end the paper by detailing methods for Thesis research and study, along with the deliverables required to produce a meaningful and applicable conclusion.

II. Technical Topic

In all of its applications, Lean manufacturing seeks to eliminate the many varieties of waste that result from plant processes. Waste is any type of accumulation that diminishes the overall value of a production facility. There are, notably, eight forms of waste that are capable of depreciating the efficiency of an operation, all of which are addressed by some principle of Lean manufacturing. The first type of waste is overproduction and generally results from neglecting to tune factory operations to the exact needs of a customer. Physically, processes that create beyond the needs of what is demanded contribute to overproduction, ultimately wasting time and resources that could be directed to meeting customer requirements in a timelier manner. The second type of waste is waiting, where machines, people, or resources enjoy excess downtime before moving to a subsequent stage of activity. Long cycle times could create waiting waste if preceding cycles are short. Lean Construction Institute also indicates that an employee that waits to raise a concern about a plant issue until, for example, the next “weekly team meeting” rather than immediately, jeopardizes the operation and extends the duration of vulnerability (“8 Wastes of Lean” n.d.). The third type of waste is excess transportation. Resources must be frequently moved to facilitate plant production and excess movements ultimately diminish throughput and create inefficiencies. The fourth type of waste is overprocessing, which is similar to overproduction, but instead of creating an excess of product, overprocessing is attributed to a lengthening of cycle time due an excess of movements within a specific process. The fifth type of waste is excess inventory, which flows from overproduction. An overabundance of resources demands adequate storage space, but ultimately makes inefficient use of the facility’s storage by virtue of the fact that the space does not directly provide value to the customer. The sixth form of waste is unnecessary motion, which typically results from a poorly designed process that requires a worker or machine to execute more movements than that which is necessary to sufficiently complete the task and ultimately deliver value. The seventh form of waste is defects and relates to the quality of a manufactured product. If the elements within a process cause damage or imperfections to a subject material, the disposal of that item could be required, meaning that all the resources that contributed to the item’s development have been processed in vain. The eighth and final form of waste is the unused creativity of employees. The principle surrounding this waste proposes that all workers at each stage of the facility hierarchy are able to contribute to Lean development, as each employee has their own experience and ideas regarding the current state of production (“8 Wastes of Lean” n.d.). Neglecting these perspectives limits the potential, reach, and reliability of any attempt to introduce Lean.

In order to develop an appreciation for how Lean can eliminate waste, we must discuss the five Lean principles outlined in the Introduction in greater detail. Value is entirely indicated by the customer, so to make a production facility efficient, robust, and able to meet the needs of the business, a client's expectations must first be taken into account. The supply and demand of the facility are the most important considerations, as the plant must discern the overall current throughput rate and how that might change across an interval of time. On a large scale, one can determine the presence of overproduction or underproduction based on whether or not the customer requirements are met. Since most businesses seek to satisfy the needs of their customers at a base level and prove their reliability, overproduction typically arises as an overlooked form of waste in an established facility and provides insight into the exact processes that contribute value to the system along with those that diminish value. Next, the value stream of a facility, or one of its relevant components, must be mapped by considering two primary components of the operation: location and time. Those responsible for Lean implementation must physically draw the progression of resources from one process stage to another. The time that resources spend at each stage must also be considered and illustrated. There are several ways to quantify process-related time, but one common way is cycle time, which is the sum of valuable time taken to produce components in a particular process along with the time not directly contributing value.[1] By mapping both dimensions of a factory, points of excess storage, time, movement, or other forms of waste will be highlighted, permitting changes to be made that

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[1] Sources were used that are not available to the general public. The information itself is not confidential, but the authors, titles, and publishers of the works cannot be retrieved.

will eliminate the superfluous. Many sources of factory waste are the result of inactivity, so the next step proposed by the Lean methodology is to create flow. In a manufacturing setting, flow is the movement that carries resources through a particular process. The value stream map permits employees to identify areas where a process is stagnant and propose changes to ultimately reduce excess downtime and maximize efficiency. The fourth Lean principle is to establish pull, which informs the creation of flow, by reducing all excess. Any movement in a factory cannot manifest in the accumulation of storage, downtime, or superfluous activity. A pull system eliminates this waste by requiring production to provide exactly what the customer requires, “pulling” resources through the system, rather than motivating a line through superfluous input. The final Lean principle is continuous improvement. After the preceding Lean principles have been implemented, employees must continually monitor the performance of the operation. By making repeated notes of where resources are traveling and developing time metrics, a process can be cyclically updated in order to adapt a facility to the many obstacles the business is likely to face.

III. STS Topic

This study will examine work in the field of manufacturing engineering and attempt to shed light on past implementations of Lean in order to identify and enumerate the best environments for such improvements and what changes must exactly be made. A relevant STS-related question that arises in this discussion of Lean manufacturing is how can Lean implementation be made safest for all employees working in a production center? In many facilities, an isolated process will have an “SQDC” board attached to it, which is typically a whiteboard in the vicinity that tracks metrics regarding safety, quality, delivery and cost. The safety metric often tracks the number of near misses or accidents that have occurred over a particular interval. Quality relates to the condition of resources as they move through the process, so the number of faults or defects will often be tracked here. Delivery analyzes whether or not a process is on-track in meeting the demands of the customer and details areas of waste that could be detrimental to the operation ("What is an SQCDP Board?" n.d.). The ordering of these metrics is not an accident, with safety being the first, and therefore the most important, benchmark. Efforts of continuous improvement related to quality, delivery, and cost cannot be executed without those dedicated to safety. Unlike the other metrics, safety is a uniquely human measure, as it has direct and drastic implications on the course of an employee's life, granting it primacy in the field of manufacturing. In addition to the many potential environments that make Lean a suitable fit, this Thesis will also examine particular Lean improvements and assess how they can be implemented in the safest manner.

In the second component of the STS discussion, Lean manufacturing will be examined from the perspective of human factors. The field of human factors engineering examines the relationship between machine and operator and seeks to improve the interactions between the two such that a more gratifying user experience proceeds. In a factory environment, regardless of installed automation control systems, human workers will always be the driving force behind production, as they are needed to operate machinery, perform quality inspections, and troubleshoot equipment. Briefly using broad brushstrokes, it is safe to say that the working environment of a factory is harsh, as an employee can be subject to loud noises, bright lights, and manual labor. Knowing this, manufacturing leaders and controls engineers must ask and understand how their proposed improvements physically affect operators. Many different parts of the body can be considered when taking human factors into account, but the five senses are a great place to start. As an example, a controls engineer developing an HMI for a pump might ask whether or not the operator has enough visual input to confirm the state of the pump without requiring him/her to crawl into a potentially dangerous environment. A floor leader might ask whether or not the background noise of machines could cause hearing degradation over time for those in the vicinity and rearrange the floor accordingly. Another aspect of human factors engineering is the relationship between technology and man's musculoskeletal system. In "Application of Lean Manufacturing Principles in Optimizing Factory Production", Sharma et al discover that, after surveying workers at a window screen production facility, an inefficient use of shelf space in a central in-plant supermarket forced operators to travel varying distances based on the type of screen moving through the process, as not all parts were available on the shelves located closeby to assembly lines. Not only did this create inefficiencies within the process and depreciate plant throughput, but the extended walking distances can place a greater strain on those working the shop floor. As a solution, the authors proposed a new layout by diminishing the dependance on the central supermarket and decentralized the necessary parts to subsidiary shelves in close proximity to assembly lines. This solution not only eliminates different types of waste, such as excess travel time and unused storage space, but places less of a burden on the operators with shorter walking distances, serving as both an effective Lean improvement and nourishment for the relationship between worker and assembly line (Sharma et al, 2018).

The eighth form of waste discussed in the previous section: wasted employee talent and potential, is quite related to the topics of STS. In "Lean Ethics: Part One - Grasping the

Situation", Kihn and Majerus detail multiple ways in which manufacturing companies have engaged in unethical behavior. They then acknowledge that a change in ethics starts with the people without neglecting any rung of the business hierarchy (Price, 2021). Given that great weight is placed on the creativity and input of all workers in a Lean environment, this system has potential to serve as a force for ethical production practices by refusing to isolate particular organizations from one another, ultimately encouraging transparency and communication and contributing to a desirable workplace.

IV. Research Question and Methods

Currently, there are many plants that could significantly improve their operation by implementing Lean manufacturing. In order to adopt the basic idea of waste elimination and direct all improvement efforts toward this goal, a Lean "mindset" must first be adopted by all levels of an organization. Then, the organizations and tools necessary for successful implementation must be arranged to adhere to a set of basic Lean principles (Aulakh & Gill, 2008). From a technical perspective, I will examine the viability of Lean in different plant environments via case studies and manufacturing data and ultimately provide the best scenarios for Lean implementation along with the required process changes. Additionally, I plan to discern the cases for when Lean manufacturing should not be used and the reasons for its omission, such as a particular process, final product, or cost-benefit analysis that introduces roadblocks. No hands-on work will be completed, as this project will involve case study analysis and data synthesis to arrive at a conclusion. There is a possibility that this discussion of Lean will involve computer models that make predictions or perform simulations. Mathematical models have already been developed that model the demand, inventory, and cycle time for a manufacturing facility (Deif, 2010). If necessary, any calculations will be performed on MATLAB and the exact details will be included in the Thesis. From an STS perspective, I will consider how Lean manufacturing can be implemented safely by considering case studies that overlap Lean methodologies with human factors research. If there is sufficient research on the subject, I would also like to consider the effect of Lean manufacturing on a company's ethics.

V. Conclusion

The technical deliverable of this assignment is enumerated and sufficiently detailed lists of manufacturing facility attributes that are fit for Lean development and those that are not. I will also provide a fabricated Lean manufacturing implementation example and demonstrate, via mathematical proof or computerized model, its effectiveness regarding plant production. The STS deliverable of this assignment is a detailed list of methods related to human factors that Lean practitioners can use when designing or improving systems for safety. Implementation of the technical deliverables will allow plant managers to quickly assess the current state of their operation and discern whether or not Lean manufacturing is a worthwhile implementation, from the perspective of increasing safety, improving quality, bolstering delivery, and reducing cost. Implementation of the STS deliverables will allow Lean manufacturing engineers and floor leaders to consider the many aspects of the human body and needs of an operator when implementing a design or improvement. This topic is not at all related to my Capstone project, which is about developing circuits and software to power data acquisition systems on a hypersonic satellite. I am, however, working with a manufacturing company after I graduate to implement and continuously improve upon Lean processes, and I find this topic far more interesting to research and read about.

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