Applying Lean Manufacturing Tools to the Management of Operational and Network Risks

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ABSTRACT

Risk management has become a growing concern for manufacturers. Academics in the field have classified risks into operational (internal), network (supply chain) and environmental (natural, political and external) risks. Lean Manufacturing tools have been used to standardize and stabilize manufacturing processes, to reduce variability, to increase machine reliability, to incorporate quality into processes and to make the link with suppliers tighter, more efficient and dependable. All of these characteristics suggest that many of the Lean tools could be used to foresee and mitigate risks, and even to react to unexpected events. In this paper we examine the most important lean tools and relate them to the variables that are changed by them. We then examine those variables to identify the risks associated to them and propose a structured procedure for lean practitioners to apply the tools they already are familiar with and take explicit advantage of them in the corporate risk management effort.

1. INTRODUCTION

Lean Manufacturing and its tools and techniques are mature and well-known ways to improve manufacturing and operations. For the last 30 years companies all over the world have applied them to streamline and make their operations more efficient, with increased levels of quality and consistent results. Lean Manufacturing strives to perform operations with more direct flows, less accumulation of work in process (WIP) and the precise amounts of space, inventory and resources required for the functioning of the business. These goals are attained more easily if every aspect of the operation occurs when, where and how it was planned. This predictability and smooth progress of business is not always the case.

In recent years Risk Management has become a hot topic for companies. It has become clear that inconsistencies in their operational processes, problems with suppliers [1] and natural disasters [2] can bring production processes, supply networks, humanitarian relief and even the economy of whole regions down to their knees. Risks, disruptions, variability and inconsistencies are natural enemies of the stable environment that Lean Manufacturing seems to require and foster

Our proposal is that, since Lean Manufacturing and its tools are widely in use and there is ample knowledge about their operation in a variety of industries [3], [4], they should also be used (where it is relevant and applicable) integrated with the risk management efforts of companies. To achieve this, we will identify the impacts that lean tools and techniques have over the production variables in the company and characterize which tools have the greatest potential to contribute to risk prevention and mitigation. We will show how the use of lean tools for corporate risk management creates a positive reinforcing loop that also improves conditions for further implementation and refinement of lean tools in the company.

The paper is organized as follows: Section 2 presents a basic background on lean tools and the effect each one has on other tools and on production variables through their application, as well as a brief background on risks and their main classification schemes, presenting the one used on this paper. In Section 3 we present the identification of the types of risks that are subject to positive impact through the application of each lean tool, and in Section 4 we propose a FMEA-based process for practitioners to prioritize the lean tools that may assist them in the corporate risk management effort. Section 5 presents the conclusions and future research.

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2. Background

In this section we will present a brief overview of the tools that are typically considered as part of Lean Manufacturing, as well as an introduction to Risk Management in companies. In section three we will use this information to relate both fields.

2.1. Lean Manufacturing Tools

There are as many classifications of Lean tools as there are authors [5]. However, we find it useful to organize them according to a progressive evolution of the capabilities of a company, in a structure of prerequisites. This structure does not imply that it is impossible to start implementing a tool until all of its prerequisites have been finished (in fact, sometimes it is useful to start implementation of some tools to make flaws in the current process evident); rather, it emphasizes the fact that each Lean tool improves certain capabilities of the company, its people and its processes. Figure 1 presents the proposed implementation structure.

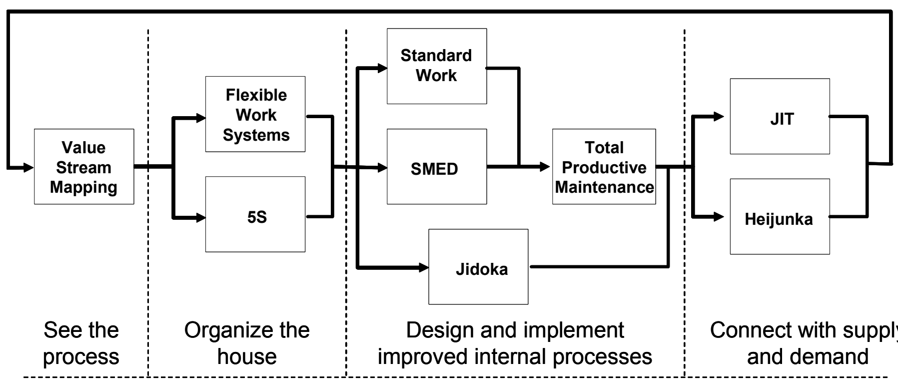

Fig. 1. Typical process for a Lean Implementation.

Now we will present a brief description of each of the lean tools. This description will be useful to understand their impact on production variables and risks.

- **Value Stream Mapping:** It is a visual representation of the flow of materials and information for the manufacturing of a product family. It collects the time the product spends in the manufacturing system, from the time a customer order arrives to final goods storage. Its main contribution is to show how much time a product spends in value-adding activities, and how much it is just waiting (non value-added activity). It highlights opportunities to increase efficiency and make the flow of materials smoother through the process.
- **5S:** Its name comes from five Japanese words that start with S (Seiri, Seiton, Seiso, Seiketsu and Shitzuke). It is a set of good practices related to the elimination of clutter and having in the workplace only those materials, equipment and objects required to do the job (Seiri), defining "a place for everything and everything in its place" and keeping closer those things used more frequently (Seiso), cleaning the workplace before and after work and preventing it from getting dirty (Seiton), standardizing the state of the workplace and the routines for cleanup (Seiketsu) and implementing follow-up procedures, checklist and cross-area audits to guarantee consistency in the use of 5S. All these improvements also have a positive impact on workplace safety. Five S is probably the cornerstone technique to build good work habits and discipline, as well as a sense of pride and ownership in the workers [6].
- **Flexible Work Systems:** This refers to organizing product families, dedicating a set of machines, a delimited physical space and a human team to each product (or part) family in what is known as a *manufacturing cell*. Cellular work systems (also known as *Group Technology*) have advantages such the cohesive nature of the work, the multiple abilities of the cell members, the rapid detection and corrective action to solve quality problems, the close control of the materials that flow through the cell and the physical proximity of equipment and team members.
- **Standard Work:** In a narrow sense, standard work refers to the determination of the *Takt Time* (the production rhythm required to keep pace with the demand), the standardization of the layout of the

workcells, the determination of the quantities of work in process required between steps of the process and the combination of manual and automatic work in the cells. A more comprehensive approach states that standard work also refers to the systems and disciplines of standardizing procedures and processes and also to the maintenance and improvement of such standards. It is crucial that every person that performs and operations does it the same way. Also, standards are necessary for training and to keep process knowledge in the company, making it structured and formal.

- **SMED:** "Single Minute Exchange of Die" refers to the reduction of setup time. A setup is the time elapsed between the production of the last unit of a certain product and the first good unit of the next product, when changing product references in a production line or cell. When setup times are long, they force companies to manufacture large lots of each product in order to reduce the total time devoted to setups. Large lot sizes cause a lot of forms of waste, because they tie up money invested in materials that are not yet sold, they create inventory that uses space in the plant floor and in storage, and they make the detection of lot-specific quality problems harder, to name a few of their undesirable consequences. That is why setup time reduction is a central aspect in lean manufacturing implementations.
- **Jidoka:** Shigeo Shingo studied the causes of defects in products, and he concluded that when something does not go according to plan it is because there was a mistake somewhere in the process. Jidoka is the practice of eliminating errors through simplification and automation of certain aspects of work. Jidoka applies a set of principles such as elimination, substitution, simplification, symmetry and asymmetry, and also devices known as *Poka-Yokes* to ensure that both process and people reduce errors, and make work less mechanical and more satisfying for people.
- **TPM:** "Total Productive Maintenance" means to transform the time used in maintenance from a time loss into a resource to improve machine reliability and performance. TPM has several pillars, and one of the most important ones is Autonomous Maintenance, where workers perform their own maintenance according to a preventive schedule.
- **Heijunka:** It is also known as *Production Smoothing*, which means to manufacture products in a sequence that resembles as closely as possible the demand mix of the market. For example, if the demand of a company is 60% product A and 40% product B, the company should alternate making three units of A and then two units of B, and repeating this sequence over and over. This sequence minimizes the lot sizes and enables the company to respond quickly to customer's orders. Obviously, a short or negligible setup time is required in order to implement Heijunka.
- **JIT:** It is the crown jewel of the lean tools for its high visibility. However, it is also a tool that requires that the system achieves a certain level of evolution before its implementation. Just in Time means to move materials in the right quantities to the place they are needed at exactly the time when they are needed. Quality, reliability and small lot sizes need to be in place, since receiving inspections need to be eliminated and suppliers must be certified. The use of material supermarkets and *Kanbans* (material release information devices) is vital to the implementation of JIT.

2.2. RISK MANAGEMENT

In recent years, manufacturing companies have been influenced by several operational trends [7], that make them more vulnerable to risks, such as:

- **Just-in-Time and Lean practices**, that make them more efficient and use less resources.
- **Globalization of supply chains** to seek lower manufacturing costs. This makes the supply networks more complex.
- **Centralization to achieve economies of scale:** Companies build bigger factories and distribution centers to operate more efficiently. Any disruption in the operation of these facilities has a large impact on the whole logistics network of the company.
- **Outsourcing of non-core activities** generates the involvement of a greater number of companies in the supply network, causing a loss of control of its operation by the manufacturer.
- **Consolidation of suppliers** makes the manufacturing company more vulnerable to disruptions in the suppliers, since there are no alternative sources for key materials and components.

These trends have caused an increase in the creation of offices of risk management in companies, as well as in the literature, consulting services and research in risk management topics [8] [9].

Kaplan and Garrick [10] presented a seminal definition of risk as a triplet of elements that define a risk scenario as the answer to the following questions:

- What can happen and what is its cause? *(Prevention and Detection).*
- How likely is it that it will happen? *(Probability).*
- If it happens, what are the consequences? *(Impact).*

This definition makes the concept of risk more manageable, as it distinguishes the areas in which practitioners need to prepare to face risks. Another part of risk management increased its importance in recent years, especially in the wake of natural disasters such as the earthquake and tsunami of Japan in 2011. It refers to how prepared a company is to continue operating and recover from large-scale disruptions in its operation. The main term in this area is *Resilience* [11].

For this paper, we will use a scheme to categorize risks proposed by Jüttner, Peck and Christopher [12]. The authors classify risks in three categories, according to their scope:

- **Organizational Risks:** Those that occur inside "our" company. Their management is our responsibility.
- **Network Risks:** Related to our connections to other companies in our supply network (customers, suppliers, suppliers of suppliers). These demand coordinated action between companies.
- **Environmental Risks:** They are outside and around the supply network. Environmental risks are hard or impossible to control. For example, weather-related risks, natural disasters, and political disruptions are considered in this category. In the face of environmental risks, it is not possible to stop an adverse event from occurring (an earthquake, an event of political unrest). Companies can try to foresee the occurrence of adverse events, build contingency plans and prepare for business continuity.

In this paper, we will consider the use of Lean tools applied to organizational and network risks.

3. Relationships Between Lean Tools and Risks

Since Lean tools generate impacts on production variables, and these production variables can also generate disruptions and cause risks, it follows that there must be a relationship between Lean tools and risk management. Figure 2 presents such relationship.

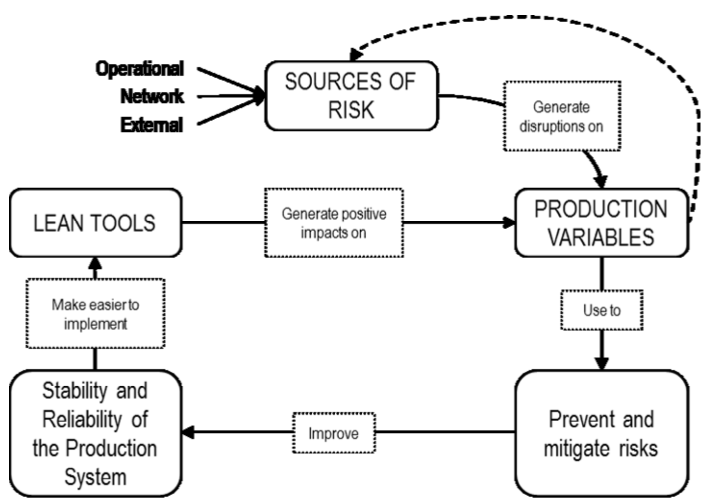

Fig. 2. Relationship between Lean tools and Risk management.

The application of Lean tools creates positive effects on the production variables, which also receive impacts from the sources of risk. In turn, production variables are used to prevent and mitigate risks and increase the stability and reliability of the production system. This increased reliability makes it possible to advance to Lean tools that are increasingly complex and have more prerequisites, as presented in Figure 1. If companies close this cycle and take advantage of the positive impacts achieved, they can jumpstart a continuous improvement cycle as Lean Manufacturing proposes.

Not all Lean tools have the same effect on the production variables. The expected impacts of each Lean tool on production variables that have effects on risks are presented next:

- **Value Stream Mapping:** It is a tool for graphical representation; it does not have a direct effect on production variables.
- **5s:** Giving order, right placement of tools and materials and visual control to the workplace might generate *faster operations*, *reduced walking, reduced needs of space* and *improved safety and ergonomics.*
- **Flexible Work Systems (cells):** With the characteristics previously explained, it is expected that they contribute to *improve product quality* and to generate *smoother material flow.*
- **Standard Work:** A standardized operation method should reduce *errors in production* that translate into operational risks.
- **SMED:** Shorter setup times enable smaller lot sizes, which make for *smoother flow* and *faster detection of quality problems.*
- **Jidoka:** This technique reduces errors in process and people, reducing *errors in production* and *improving product quality.*
- **TPM:** Productive Maintenance increases reliability of the system, which *reduces unscheduled machine stoppages.*
- **Heijunka:** Making smaller lot sizes of each product, and doing so more frequently, generates *smoother material flow.*
- **JIT:** Using parts supermarkets and kanbans to control material flow will make *materials to flow more smoothly,* and it *reduces uncertainty in supply*, both from external suppliers and among sections of the same company.

Several production variables are impacted by more than one Lean tool. Table 1 summarizes the production variables that can be affected by the Lean tools, and relates them to different types of risks.

Table 1. Production variables and risk types.

Effect on production variables	**Types of risks**
Improved safety and ergonomics	Accidents may stop work.
Improve product quality	Quality problems stop work and require additional effort to solve.
Smoother product flow	Disruptions to flow may cause production delays.
Reduce errors in production	Incorrect procedures cause quality issues and accidents.
Reduce unscheduled machine stoppages	Stoppages delay production and may cause unforeseen expenses and effort to repair machinery.
Reduce uncertainty in supply	Disruptions in supply cause delays in material flow that vary in intensity and duration.

All these risks are under the Operational or Network categories, depending on who is the recipient of the materials in each instance. For example, if there is a delay on the delivery of a product caused by a quality problem in the supplier, it is a network risk. If one of our own machines breaks down and our production stops because of it, it is an operational risk. In section 2.2 we mentioned that operational and network risks are more susceptible to prevention and mitigation than environmental risks. This is consistent with the Total Quality Management philosophy (embedded in Lean Manufacturing) that states that prevention is better than correction.

4. Risk Management Methodology

We propose a methodology that prioritizes the implementation of Lean tools that help manage risks. This methodology is to be used with ongoing Lean implementations and Risk Management efforts, not as a separate implementation effort. Implementing different production systems or company-wide improvement efforts back to back or at the same time creates difficulties for employees, as they perceive these efforts as conflicting and sometimes incongruous, turning them into short-lived management fads [13]. Figure 3 presents the methodology to integrate Lean tools with risk management and prioritize their implementation.

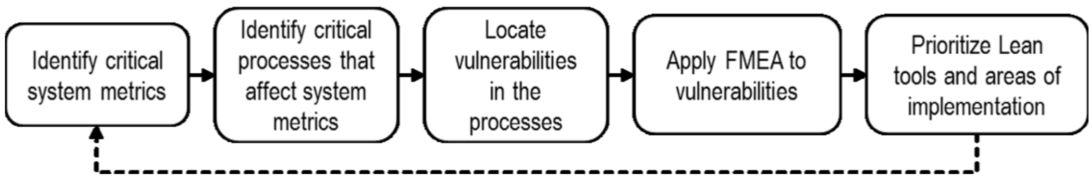

Fig. 3. Prioritization of Lean tools for risk management.

We will explain each of the phases in this sequence:

- **Identify critical system metrics:** It is necessary to distinguish what is important for the functioning of the system. In companies that are implementing Lean manufacturing there are two different types of metrics [14]: Results-oriented metrics and process-oriented metrics. Results-oriented metrics are related to business objectives and are visible to customers, such as on-time deliveries and product quality. Process-oriented metrics are related to internal progress in the implementation of Lean manufacturing, such as the number of suggestions per employee per year.
- **Identify critical processes that affect system metrics:** Lean manufacturing will conduce to the improvement of all the process in the company. However, not all of the areas and processes are equally critical for the attainment of the desired level of the system metrics. For example, if a company makes a wide variety of products that all share an assembly workcell, it might well be that this cell is critical in terms of production rates, quality level or product finishing. It might make sense to start lean implementation efforts in such a central workcell.
- **Locate vulnerabilities in the process:** This is an exercise in extreme pessimism. Take the selected processes and ask yourself: “What could go wrong? What would cause my process to stop working, to manufacture fewer units than my quota, to generate product with substandard quality levels?” These are the inputs to choose which risks will be subject of attention.
- **Apply FMEA to vulnerabilities:** Failure Modes and Effects Analysis (FMEA) [15] is a structured tool that takes possible failures and analyses what could fail, what could be the cause of the failure and its probability of occurrence, what is the severity of its effects and what is the probability of detecting the failure. We then assign a score from one to ten to Severity (10 means a stronger disruption, a costlier adverse event), Probability of Occurrence (10 means a higher probability of occurrence) and Probability of Detection (10 means a *lower* probability of detection). Multiplying these three scores we obtain the Priority Risk Index (PRI). The higher the PRI, the more critical this risk with its associated cause and controls are.

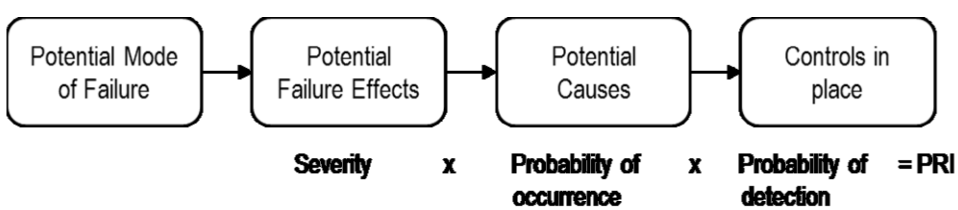

Fig. 4. Failure Modes and Effects Analysis (FMEA).

- **Prioritize Lean Tools and areas of implementation:** In the second step of this analysis we found critical process areas to monitor. Then, the most important risks were discussed for these areas. Now, we need to rank the risks based on their Priority Risk Index and select those whose causes are consistent with the list of risks presented in Table 1 (Accidents, Quality problems, Disruptions to flow, Incorrect procedures, Machine stoppages and Disruptions in supply). Based on this selection procedure, we will find the Lean tools that may help in each critical area and define their implementation as a priority.

5. Application Example

MMP is a medium-sized company, located in the vicinity of Cali, Colombia. MMP manufactures office furniture and partitions. Their manufacturing facility makes products such as working surfaces, filing cabinets, office storage and small pieces of ready-to-assemble furniture. They have several small local suppliers of wood-related products, metal products, cardboard, plastics, cloth, glass and other raw materials. They have been implementing Lean Manufacturing tools for some years now, and due to recent disruptive events (community protests blocked the flow of materials to the plant) they have recently received a mandate from the Board of Directors to undertake a corporate risk management effort. The Director of the Office for Continuous Improvement is worried that this new interest of the company will create a lot of redundant effort, so she asks for some time to verify which of the Lean tools the company knows might be applied in the risk management effort. She decides to follow the flowchart proposed in Figure 3.

- **Identify critical system metrics:** Customers are particularly sensitive to the lead time of their orders and the quality of their products.
- **Identify critical processes that affect system metrics:** MMP identified that the timely arrival of their raw materials is critical for the achievement of the lead time that is quoted to the customers (external process). Also, the line of TR components (common to many finished products) has quality issues not entirely solved yet (internal process).
- **Locate vulnerabilities in the process:** XYZ is a supplier of MMP's, and it recurrently has trouble delivering its materials on time to MMP (network risk). The TR line of components has a machine that applies hot glue to a plastic edge to finish working surfaces, but it tends to overheat and shut down, causing unscheduled stoppages (operational risk).
- **Apply FMEA to vulnerabilities:** MMP works with the supplier XYZ to discover that their highest risk priority in the supply of materials is a change in priorities in the finished products area of XYZ. When an urgent order arrives, XYZ takes whatever finished product is available and ships it out to preferred customers, leaving MMP's orders incomplete and generating expedited orders at XYZ. This occurs at least six times a year. MMP fails at detecting this problem rapidly because they do not have a system to track the status of outstanding supplier orders. When materials from XYZ do not arrive when needed, the plant at MMP has to stop and wait for them. In this case, the failure mode has high probability of occurrence, high severity of impact and low probability of detection. In relationship with the internal quality problem, the most critical problem is that the machine overheats frequently (once a week), due to the fact that there is an apparent problem with the ergonomics of the workstation and the process runs more slowly than it should. This failure is easily detected, but if it occurs it stops the production line for at least three hours. In this case, the failure mode has high probability of occurrence, high impact on the process and high probability of detection, therefore its priority risk index is medium-high.
- **Prioritize Lean Tools and areas of implementation:** According to Table 1, MMP might implement a Kanban system with XYZ that generates a clear discipline in material flow. Assigning kanban cards to finished products ensures that the products are not arbitrarily assigned to orders from other customers. Also, MMP will always know which materials are pending for arrival and will be able to control them effectively. To solve the quality problem related to the overheating machine, the application of Jidoka will solve the ergonomic problem, making the operators work more safely and comfortably and keeping the right process speed to prevent overheating in the machine.

6. Conclusions and Future Research

On this paper we have shown that there is a relationship between Lean tools and risks. Lean tools improve the functioning of the production system by affecting production variables. These production variables might be the source of certain risks. By implementing Lean tools and using them as resources to improve risk management we are creating a more stable production environment, which in turn makes it easier to implement further and more demanding Lean tools.

Lean tools DO NOT solve every type of risk. This paper does not propose how to manage all risks faced by a company using Lean tools, rather, since it is very common that companies have risk management systems and also Lean offices or are implementing Lean, we propose a way that make both efforts consistent and take advantage of Lean tools as risk reducers and mitigators.

Every Lean tool helps to improve certain production variables, but it is their coordinated implementation and continued use what makes a continuous improvement successful. Lean manufacturing has many systemic effects that result from a tool creating a better environment for the implementation of the next one.

For future work, it would be interesting to explore which Lean tools might be of use for External risks, as well as to explore which tools are useful to improve system-wide characteristics such as flexibility and resilience (the ability to recover quickly from a disruptive event). In these uncertain times, tools that make a company more adaptable and capable to recover from foreseen and unexpected events are very attractive. Lean manufacturing has always been useful for stable environments, but if we identify and foster positive capabilities developed by it, it would be possible to use lean tools to create companies that are more robust, resilient, adaptable, and therefore durable.

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