UNVEILING THE INHERENT PARADOXES IN LEAN MANUFACTURING

Bojan Jerinic [1] [ORCID 0009-0009-5783-363X], *Nemanja Sremcev* [1] [ORCID 0000-0003-2552-1008], *Branislav Stevanov* [1] [ORCID 0000-0002-0211-2271], *Ilija Cosic* [1] [ORCID 0000-0001-9796-4452]

[1] *University of Novi Sad, Faculty of Technical Sciences, Department of Industrial Engineering and Management, Serbia*

Abstract: *Lean manufacturing stems from the Toyota Production System renowned for its emphasis on waste reduction, continuous improvement, and customer value, it has been widely adopted by organizations seeking operational excellence. However, the methodology possesses some inherent paradoxes which contradict the guiding principles of the methodology and can represent obstacles during implementation or even the comprehension of the methodology. This paper aims to identify and discuss the paradoxes which lie in the methodologies, tools, and principles of Lean manufacturing such as Jidoka, Just-in-Time etc. through a comprehensive analysis of existing literature, case studies, and empirical evidence, this paper aims to deepen the understanding of these paradoxes and Lean thinking.*

Key words: *Lean, Manufacturing, Paradox*

1. INTRODUCTION

Optimizing processes has been at the heart of industry since the beginning, eliminating unnecessary steps, lowering costs of production, enhancing quality, and shortening lead times all for the goal of maximizing value and increasing profitability, no methodology has exemplified this better than Lean manufacturing. With its goal of maximizing value-added activities by eliminating waste or optimizing and shortening value added activities it achieves the shortening of Lead times and thus expediting cash flow it achieves more with less than other methodologies applied across industry. Lean, a manufacturing philosophy derived from the Toyota Production System has been widely adopted across all types of industries (Liu & Yang, 2017; Maciąg, 2019; Sarhan et al., 2017; J. P. Womack et al., 1990). At its core it sees two type of activities value-added and non-value added.

1. Value-Added Activities: Value-added activities are those tasks or steps that directly contribute to the creation of value as perceived by the customer. These activities transform raw materials, components, or information into the final product or service that the customer is willing to pay for. Value-added activities enhance the form, function, or quality of the product, meeting the customer's needs or desires. Examples of value-added activities include assembly, customization, design, and testing. The goal in Lean is to identify, prioritize, and optimize value-added activities while minimizing or eliminating non-value-added activities.
2. Non-Value-Added Activities (Waste): Non-value-added activities are tasks or steps that do not directly contribute to the creation of value and can be eliminated without affecting the end product's quality or customer satisfaction. Identifying and eliminating non-value-added activities is a core focus of Lean principles.

Lean recognizes that each system and each process contain both types of activities, it also recognizes that there are other types of wastes in the system(Krafcik, 1988; Taiichi Ohno, 1978; J. Womack & Jones, 2003), the three types of wastes in the system according to Lean are:

1. Muda - The Waste of Non-Value-Adding Activities: Muda refers to any activity or process step that doesn't add value to the product or service from the customer's perspective. These are tasks that can be eliminated without affecting the outcome. There are various subtypes of muda, including:
   - Transportation: Unnecessary movement of goods or materials.
   - Inventory: Excess inventory that ties up capital and increases the risk of obsolescence.
   - Motion: Unnecessary movement of people or equipment.
   - Waiting: Idle time when resources are not actively engaged in value-adding tasks.

- **Overprocessing:** Performing more work than required, adding features that the customer doesn't value.
- **Overproduction:** Producing more than what the customer demands, leading to excess inventory.
- **Defects:** Quality issues that lead to rework, scrap, or customer dissatisfaction.
- **Skills:** Not utilizing the talent and skills of workers wastes their potential.

2. **Mura - The Waste of Irregularity or Inconsistency:** Mura refers to the unevenness or inconsistency in workloads, processes, or outputs. This irregularity can lead to inefficiencies, overburdening some parts of the process while leaving others underutilized. It can also lead to increased lead times, lower quality, and increased stress on employees. Mura can manifest in different ways, such as fluctuating demand, uneven work distribution, or inconsistent process flows.
3. **Muri - The Waste of Overburden:** Muri refers to overburdening or straining resources beyond their capacity, which can lead to fatigue, errors, and reduced overall efficiency. This waste occurs when unrealistic demands are placed on people, equipment, or processes. Overburdening can negatively impact the well-being of employees and the reliability of processes, resulting in increased errors, accidents, and burnout.

2. PARADOXES

To eliminate waste from processes, Lean philosophy employs a rich array of methods, tools, and techniques, all meticulously designed to identify waste and excise it from organizational processes. However, it is through the practical application of these methods, tools, and techniques that organizations often encounter the very paradoxes that are subtly nested within the fabric of Lean philosophy.

A paradox, by definition, is a construct—an assertion, proposition, situation, or concept—that initially exhibits traits of self-contradiction, logical absurdity, or apparent impracticality. Yet, paradoxes are far from mere puzzles to be solved; when subjected to thorough examination, these surface contradictions possess the remarkable capacity to unveil concealed truths, intricate intricacies, or profound insights (W. V. Quine, 1962). Paradoxes hold a pivotal role in challenging conventional thought patterns, compelling us to reevaluate our assumptions and beliefs. Found not only in philosophy but also in literature, mathematics, and numerous other disciplines, paradoxes serve as catalysts for contemplation, sparking discussions, and pushing the boundaries of our cognitive grasp.

The manifestations of paradoxes are as diverse as they are intellectually stimulating, encompassing logical paradoxes, semantic paradoxes, self-reference paradoxes, and beyond. Their central function lies in expanding our intellectual horizons, revealing the subtleties and complexities hidden within seemingly straightforward concepts (Michael, 2012). Some paradoxes illuminate fresh perspectives and catalyze groundbreaking innovations, while others persist as enduring philosophical enigmas, captivating the minds of thinkers across generations (Nicholas, 1985).

In the context of this paper, Lean paradoxes (as outlined by Emi et al., 2008) represent the self-contradictory tools, principles, methods, and techniques intricately woven into Lean philosophy. While the overarching goal of Lean is to reduce waste, these paradoxes highlight a nuanced reality: in the process of waste reduction, waste is often shifted from one form to another. This subtle but profound paradox underscores the complexity and depth of Lean philosophy, prompting organizations to not only identify waste but also to grapple with the intricate dance of waste transformation within their processes. Through the exploration of these Lean paradoxes, this paper seeks to shed light on these multifaceted challenges and offer insights into how organizations can navigate and harness them to drive continuous improvement and operational excellence.

Lean paradoxes

In the world of Lean philosophy, numerous paradoxes lurk beneath its seemingly straightforward principles. However, in the following section of this paper, we will shine a spotlight on two pivotal paradoxes that often take center stage in Lean discussions: Just-in-Time (JIT) and Jidoka. These concepts are not just integral but are often regarded as the main pillars of the Toyota Production System (TPS), which has set the gold standard for Lean manufacturing.

JIT, or Just-in-Time, is a Lean principle that places a premium on minimizing waste and optimizing the flow of production. Its core tenet revolves around producing and delivering items precisely when they are needed, with an aim to eliminate inventory waste and reduce lead times. On the other hand, Jidoka, another cornerstone of the TPS, centers on infusing quality into the production process and empowering workers to detect and address issues immediately. The synergy between these two principles, JIT and Jidoka, is what gives the TPS its remarkable efficiency and effectiveness.

However, it's important to recognize that despite their undeniable effectiveness in Lean philosophy, both JIT and Jidoka can present paradoxes or challenges when translated into real-world manufacturing scenarios. In this paper, we will embark on a journey to explore these paradoxes within the broader context of Lean principles and how they influence the overall efficiency and effectiveness of the TPS.

Within each of these pillars, a plethora of tools, methods, and techniques are nested. For JIT, these include well-known approaches like Kanban, Pull systems, Heijunka, and more. These tools serve as practical implementations of JIT principles, aimed at achieving the elusive goal of producing and delivering goods precisely when needed. Likewise, for Jidoka, tools such as Poka-Yoke and Andon play crucial roles in building quality into the process and empowering workers to address issues promptly.

These nested tools and techniques are not just practical manifestations of JIT and Jidoka but are also valid representatives of the Lean paradoxes. As we delve deeper into the paradoxes associated with JIT and Jidoka, we will explore how these tools, seemingly designed to enhance efficiency, can sometimes introduce complexities and trade-offs that challenge the very essence of Lean philosophy. Through this exploration, we aim to shed light on the intricate nature of Lean paradoxes and provide valuable insights for organizations striving to embrace Lean principles while navigating the nuances and challenges they present.

Just-in-Time (JIT)

Just-In-Time (JIT), a renowned manufacturing and inventory management approach, stands as a beacon of efficiency in the world of production. JIT's core objective is to produce and deliver goods precisely when they are needed, orchestrating a synchronized dance between supply and demand. This approach holds the promise of minimizing waste and significantly reducing excess inventory (Ohno & Mito, 1992).

One of JIT's fundamental principles is to eliminate inventory, which aligns with Lean's overarching goal of waste reduction. By ensuring that goods are produced only when they are needed, JIT combats the waste associated with overproduction and excess stockpiles of inventory (a form of muda). However, the pursuit of this Lean ideal through JIT can give rise to another type of muda, namely, transport.

In JIT systems, to maintain the delicate balance between supply and demand, more frequent deliveries are required compared to traditional push systems (SÁEZ-CARRAMOLINO et al., 2019; Storhagen & Hellberg, 1987). While this approach effectively eliminates excess inventory, it introduces the need for increased transportation. The heightened frequency of deliveries necessitates additional transport activities to move the same quantity of goods, which can be seen as another form of waste, or muda.

This concept becomes evident when examining a simple example (Table 1). Imagine a manufacturing facility implementing JIT principles. As orders for goods are received, production is initiated immediately, and goods are delivered as soon as they are ready. This process eliminates the need for large inventory stockpiles. However, it also means that transport activities must occur more frequently to ensure timely deliveries. This increased transportation, although necessary for JIT's success, can be seen as a potential source of waste in the form of excess transport.

Table 1: JIT Paradox

Type of delivery	Goods per delivery	Size of good (m^2)	Distance per delivery (km)	Number of trips	Inventory stored	Space used (m^2)	Total transport distance (km)
JIT	5000	1	500	3	5000	5000	1500
Traditional	15000	1	500	1	15000	1500	500

There are a couple of assumptions for the example, the first one being that the JIT system works in 3 shifts therefore it requires a delivery for every shift, and that both systems are supplied from the same supplier.

Jidoka

Jidoka, a foundational concept in Lean manufacturing, refers to the practice of building quality into the production process and empowering workers to stop or address issues immediately when abnormalities or defects are detected (Tri et al., 2018). Jidoka emphasizes installing value and quality into products; therefore, it places a significant focus on reducing defects, a type of muda (Abed & Ibrahim, 2018).

The application of Jidoka is a crucial aspect of Lean manufacturing, as it not only enhances product quality but also prevents the accumulation of defects and waste. However, it's important to note that the implementation of Jidoka may require stopping the production line in some situations to address issues promptly and avoid the propagation of defects, which aligns with the Lean principle of "stop the line." This action, while essential for quality control, can create another type of muda, which is waiting.

The concept of waiting as a form of waste becomes evident when we consider a simple example (Table 2). Suppose a defect is detected at a particular workstation during the production process. In line with Jidoka principles, the worker stops the production line to address the issue and prevent further defects from being produced. While this immediate action aligns with Lean's focus on quality, it can lead to a temporary halt in production, resulting in workers downstream waiting for materials or components to resume their work. This waiting time can be considered a form of waste, as it adds no value to the product and can impact overall production efficiency.

Table 2: Jidoka Paradox

Type of production	Goods to produce	Size of good (m^2)	Stopping the line (min)	Number of stoppages	Defective products	Rework time per defective (min)	Storage space for rework (m^2)	Total waiting time	Total rework time
Jidoka	10000	1	10	20	200	1	200	200	200
No stoppage	10000	1	10	0	800	1	800	0	800

The example in Table 2 shows an example of a production system which would stop the line in case of a quality issue, against a production system which would not stop the line and simply continue production and store the products with quality issues for rework. A couple of assumptions were made in the example, the first being that stopping the line and solving the problem would reduce the chance of the reoccurrence of the problem, and that the only stoppages for both systems could be only due to quality issues.

3. RESULTS

In the previous section two examples of Lean paradoxes were shown JIT and Jidoka, from the JIT example it can be derived that JIT shifts the muda from inventory to transport which can be seen in *Table 1* where it is shown that for the same amount of goods given the assumptions, a production system will use more storage space for inventory and have higher inventory, but have less transport in a traditional production system, against a JIT system which will shift this so that a system will have more total transport and have less inventory and use less storage space. This example shows that JIT is a Lean paradox that shifts muda from one type to another.

The Jidoka example shows in *Table 2* that a production system with no stoppages under the assumptions produces more defective products, uses more storage space for defective products, and spends more time on rework but has less stoppage time (waiting time) as opposed to a system which utilizes Jidoka which will have less defects and use less space for storage of defective products, less rework time but will have more stoppage (waiting) time. This example again shows another Lean paradox which shifts the muda from defects to waiting.

4. DISCUSSION

While Lean principles have repeatedly demonstrated their prowess in enhancing operational efficiency and productivity, the paradox emerges when we contemplate the fate of waste within this framework. Does Lean's systematic approach truly eradicate waste, or does it merely metamorphose it into different shapes and sizes, lurking in the shadows of improved processes?

This paradox beckons us to shift our focus from the binary perspective of "eliminating waste" to a more nuanced understanding of "transforming waste." In essence, waste is not entirely eradicated but rather repurposed, sometimes unintentionally, within the system. This shift in perspective compels us to reevaluate which forms of waste wield the most significant impact on organizational success.

The essence of Lean paradoxes lies in the recognition that the Lean journey is not a straightforward path to waste eradication; it's a journey of continuous transformation and optimization. While Lean methodologies indeed lead to improved efficiency, reduced costs, and enhanced product quality, they do so by redirecting waste into more manageable forms. This raises questions about the true efficacy of this approach and whether the benefits outweigh the complexities it introduces.

Therefore, the core inquiry emerges: does Lean's ability to reconfigure waste genuinely benefit organizations, or does it inadvertently introduce new layers of complexity, giving rise to these perplexing paradoxes? To unravel this conundrum, organizations must embark on an introspective journey that delves into the subtle intricacies of Lean implementation.

In summary, Lean paradoxes compel us to reconsider our fundamental understanding of waste and its role within Lean methodologies. By acknowledging that waste is not eliminated but rather transformed, we open the door to a more holistic perspective on Lean's impact on organizational efficiency and sustainability. This exploration encourages organizations to embrace the complexities and contradictions inherent in Lean principles, ultimately leading to a more profound and comprehensive understanding of Lean's true implications.

5. CONCLUSIONS

This paper delves into paradoxes inherent within Lean philosophy, using foundational examples from the TPS pillars. While focusing on two paradoxes, it acknowledges the presence of others like Jidoka and the interplay between improvement and standardization. The central inquiry emerges: does Lean genuinely eradicate waste or orchestrate its transformation into new forms? This prompts a reevaluation of how waste is understood within the Lean framework, compelling organizations to dissect its impact on operational efficiency and sustainability.

In essence, this paper serves as a gateway to understanding the intricate nature of Lean paradoxes. By exploring these paradoxes, it encourages organizations to contemplate waste not as an absolute entity to be eliminated, but as a dynamic force that undergoes shifts and conversions within the Lean context. This exploration fosters a deeper appreciation of Lean principles, urging a comprehensive assessment of their implications in the pursuit of operational excellence.

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