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Using the Lean-Based Safety Leadership Framework to Improve Operational Efficiency and Reduce Occupational Risk: Evidence from a Case Study

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Abstract: This study explores the integration of Lean methodologies with occupational safety enhancement in an industrial context. Conducted in a renown Rope factory, the research utilized an Action Research methodology guided by a novel Lean-Based Safety Leadership Framework. Through the implementation of Lean tools such as SMED, 5S, Poka-Yoke, and Visual Management, it is possibe to improve both operational efficiency and occupational safety. A Safety Efficiency Value Stream Mapping (SEVSM) approach was employed to diagnose risk points and inefficiencies within one of the factory's sectors. The intervention led to a significant reduction in operational risk and improvements in productivity, validating the framework's effectiveness as a dual-propose tool for safety and efficiency.

Keywords: Lean Safety, Shingo Model, Lean tools, Continuous Improvement, KBIs

1. INTRODUCTION

The health and safety conditions of workers have become an increasingly important area of attention for organisations (Sá et al., 2025; Badea et al., 2024), even though it still remains a critical challenge across industrial environments, especially in sectors with repetitive manual tasks and complex machinery (Mixafenti et al., 2025), where the application of specific management tools is sought to improve safety (Małysa, 2025;).

While Lean manufacturing philosophies are widely adopted to enhance productivity and eliminate waste, their effect on workplace safety is still under-evaluated with divergent opinions among researchers.

The primary objective of this study is therefore to assess the impact of Lean tools implementation on both safety and productivity within an industrial setting by addressing the following core problem: Can Lean tools be effectively leveraged to emphasize occupational safety without compromising productivity? The hypothesis guiding the research posits that a structured framework integrating Lean principles with safety-focused evaluation metrics can simultaneously reduce operational risks and emphasize process efficiency.

The remainder of the paper is structured as follows: Section 2 comprises the methodology for conducting the case study. This is followed by the results in Section 3. The paper concludes with a discussion of the results and conclusions, as well as limitations and future research avenues.

2. METHODOLOGY

The chosen research methodology was Action Research, which supports iterative intervention and continuous feedback (Susman & Evered, 1978). The process followed five stages: diagnosis, planning, implementation, evaluation, and reflection.

The host company for this study was a Portuguese synthetic textiles company. This company is the European pioneer in the production of wires, ropes, nets, synthetic and natural raw materials, being nowadays the biggest producer of agricultural wire in the world.

To operationalize the interventions, a Lean-Based Safety Leadership Framework was developed. This framework integrates the Shingo Model (Bravo-Sanchez et al., 2018), Key Behavioral Indictors (Griffin & Hu, 2013), Lean and Six Sigma tools (Furterer & Elshennawy, 2005), and principles of continuous improvement. It provides a nonprescriptive approach adaptable to various industrial contexts, emphasizing proactive safety management through leadership engagement and systematic behavioral evaluation.

The primary diagnostic tool used was the Safety Efficiency Value Stream Mapping (SEVSM), which combines traditional Value Stream Mapping with risk assessment parameters (Marques et al., 2021). The NTP 330 semiquantitative method was used to assign risk scores to workstations, considering factors such as equipment layout, worker posture, and machine interface.

Lean tools were selected based on their alignment with identified risk categories:

- SMED: To minimize setup times and reduce equipment-related risks (Almomani et al., 2013).
- 5S: To organize space and eliminate ergonomic hazards (Sá et al., 2021).
- Poka-Yoke: To reduce human error (Ulewicz & Lazar, 2019).
- Visual Management: To address spatial and communication deficiencies (Furman & Małysa, 2023).

This study used as method of approaching the Lean-Based Safety Leadership Framework, methodology developed throughout a literature review.

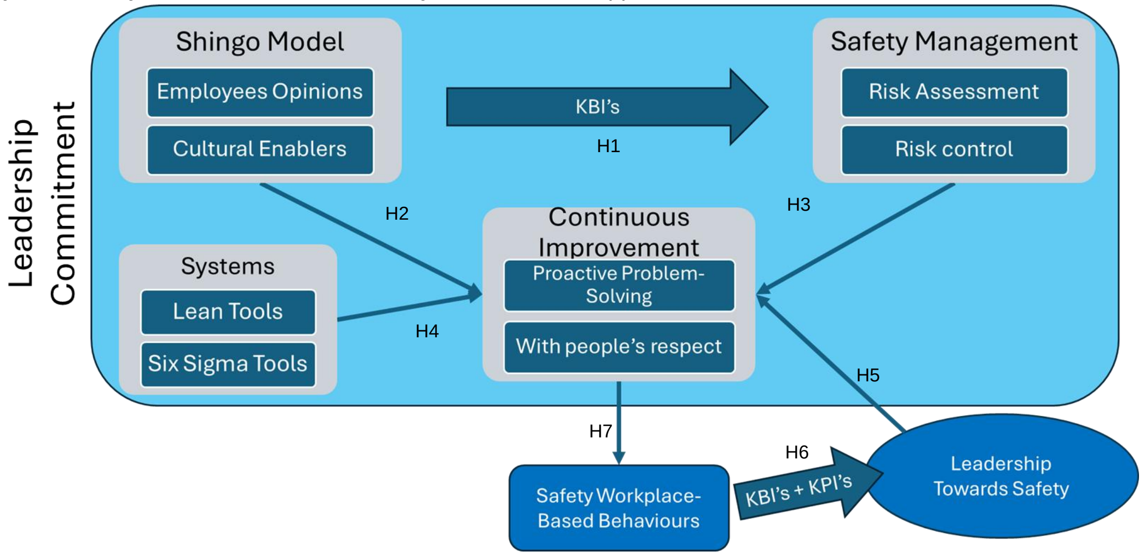

Fig. 1. Lean-Based Safety Leadership Framework

The rationale behind the proposed framework is justified by:
H1 – The Shingo Model enhances Safety Management through embedding Cultural Enablers aligned into organizational practices, with KBIs serving as measurable tools to assess and drive operational excellence (Saeed et al., 2021);
H2 – The Shingo Model improves Continuous Improvement through the integration of management and systems theory (Edgeman, 2018; Saeed et al., 2021);
H3 – Effective Safety Management in Lean Construction highlights Continuous Improvement through the reduction projects waiting times and defects, increasing workflow, productivity, and quality (Zeng et al., 2011);
H4 – Systems enhance Continuous Improvement through synergizing Lean and Six Sigma principles to improve quality, reduce variation, and exclude waste, with growing applications beyond manufacturing, including local government services, (Furterer & Elshennawy, 2005; McLean et al., 2017; Henrique & Godinho Filho, 2020);
H5 – Safety Leadership enhances Continuous Improvement in the construction industry through adopting a positive safety culture, increasing safety performance and reinforcing Safety Management Systems by communication, and employee training (Zuschlag et al., 2016; Matsubara et al., 2008);
H6 – A combination of transformational and active transactional leadership increases safety behaviors through the adoption of a positive safety climate, with transactional leadership promoting participation and transactional leadership guaranteeing compliance (Griffin & Hu, 2013; Fernández-Muñiz et al., 2017);
H7 – Continuous Improvement increase Safety Behaviors through the integration of safety assessment into management systems, using AI-driven risk evaluation to prioritize corrective actions effectively (Menanno et al., 2021; Curcuruto et al., 2019).
Firstly, before the SEVSM construction process, the data from the previous 5 years was collected, so that an objective could be outlined. It was possible to observe, for the period between 2020 and 2024, the number of employees, in average, the number of work accidents, the number of work accidents with medical leave, the quantity of worked hours, and the quantity of hours lost.

It was then possible to verify that, in average, there are 32 work accidents per year, of those, three resulted in medical leave, there were about 151,999 worked hours and 461 lost hours per year, due to accidents in the Ropework sector.
To gather knowledge about the material and information flow since the material reception to the shipping warehouse, considering the productive process of the 12-strand cord, the second step of this methodology is taken: the construction of the current state map (Figure 2).

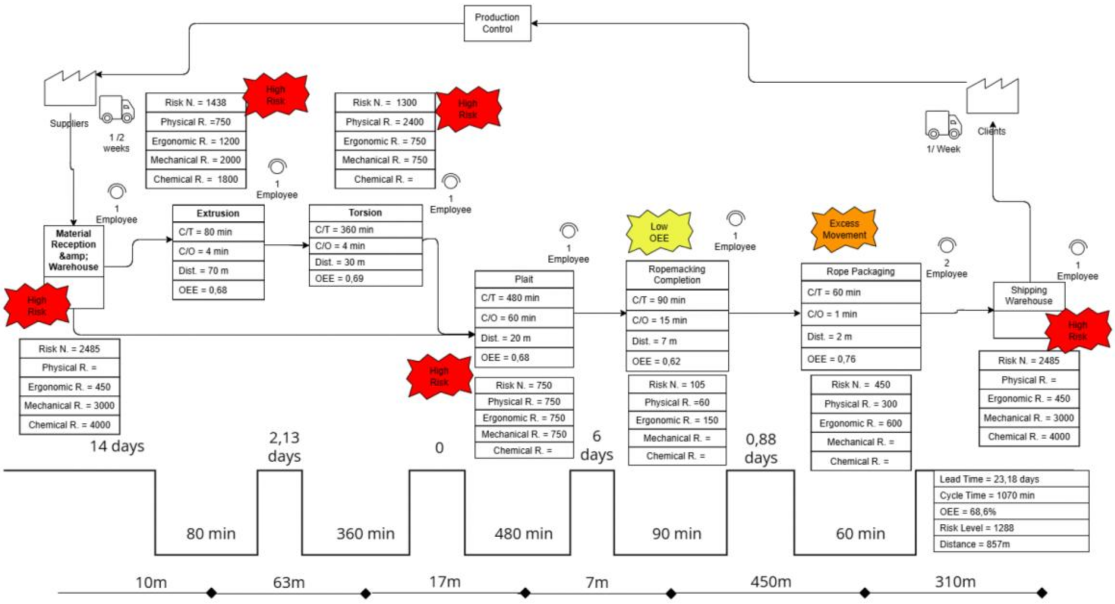

Fig. 2. SEVSD current state map

To do that, there was a need to proceed to the risk evaluation, with the chosen methodology NTP 330 simplified risk evaluation system, being globally applied in numerous industries not only because it is the methodology applied within the organization but also due to utilizing three different factors to measure the risks, level of deficiency, level of exposure and the level of consequences of the work accident.
To achieve the needed data for the proposed methodology, and to join forces with the proposed methodology, it was needed to gather employees from all hierarchical levels, and together with their opinions on the risks that they are exposed as well as the hidden risks existent, and all operation times needed to build the current state map. When a consensus was achieved, the data was collected, so that was possible to construct the current state map.
Considering the third step of the SEVSM methodology, the construction of the Future State Design is the establishment of the intended objective to accomplish. Through the existent problems in the current flow of value demonstrated in the previous map. Thus, to understand the improvements that needed to be implemented, with the application of Lean tools, considering the associated risks, productive difficulties and problems involving the efficiency of each workstation.
All things considered, the ropework sector future state Safety Efficiency Value Stream Design (SEVSD), is illustrated in Figure 3.

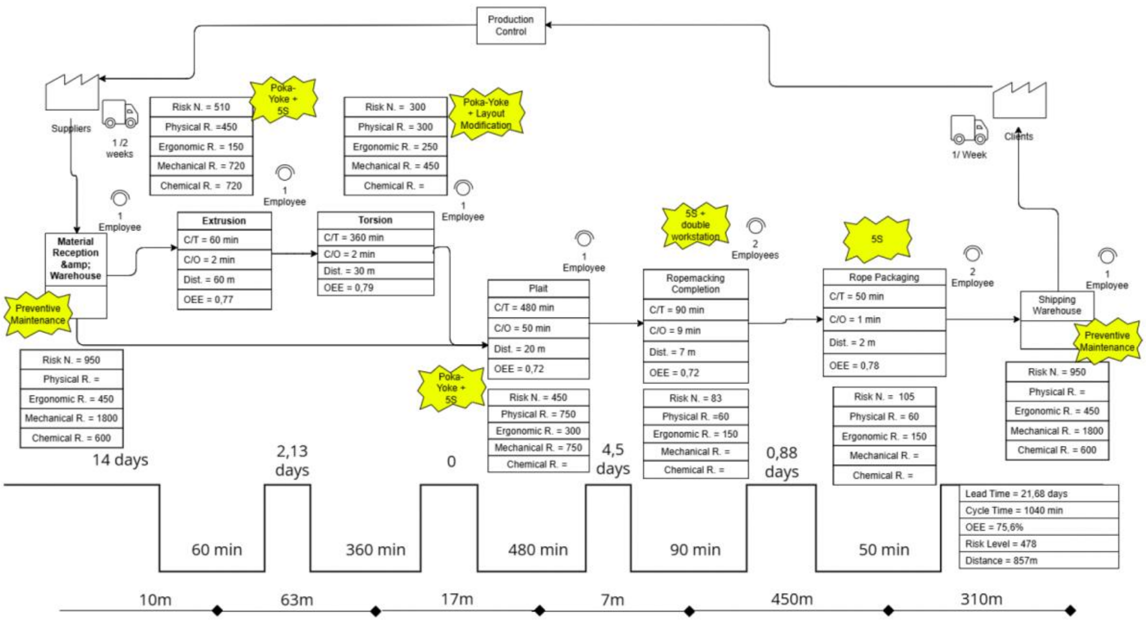

Fig. 3. SEVSD future state map

Possessing in sight the fourth step of the SEVSM methodology, the action plan should indicate all improvement opportunities, related to the previous map, in a manner to solve the encountered problems. Besides, the plan should prioritize the more critical aspects, according to the risk level and OEE. Thus, actions receive a score, in agreement with safety and productivity priorities, as possible to observe in Table 1.

Table 1. Tools and Method According to Priority Level

Tools/Method to utilize	Safety	Productivity	Total
5S – Extruder platforms floor/ surrounding floor	5	4	20
Duplication of the workstation – Ropemaking Completion	3	5	15
Poka-Yoke – Raw material feeding (Extruder)	4	5	20
Visual Management – Delimitation of the area to position production and empty reels and carts	3	4	12
Poka-Yoke – replacement of reels in the ring twisters	3	4	12
Visual Management – Delimitation of the area to position production and empty reels	3	4	12
Poka-Yoke – Reels positioning system in ring twisters	3	5	15
Poka-Yoke – Table to improve ergonomics in ropemaking completion (Production flows Bottleneck)	2	3	6
5S – Reorganization of packaging films to easier access	3	2	6
Layout Modification – Shortening the distance between the feeding reels and T2TR twister	4	3	12

As possible to observe in Table 1, the tools to implement, that present a higher priority score, related to productivity as well as safety, are the 5S in the surroundings of the

extruders, the Poka-Yoke on the two main extruders feeding system, the Poka-Yoke in the Ring Twisters feeding system and, a possible Layout Modification On the T2TR twisters, and the duplication of the Ropemaking Completion workstation.
According to the available time for the analysis and tools implementation, it was decided to focus on the two tools that can critically influence the productive processes, and represent the biggest increases in production, being the Poka-yoke on the extruders' feeding system, the Poka-Yoke system on the Ring Twisters feeding system, and the duplication of the Ropemaking Completion workstation, ending with a questionnaire to evaluate the modifications implemented according to the employees'.
The questionnaire consists of a series of 5 questions - one related to how physically demanding their work is, and two for each intervened section concerning how the intervention modified their workstation in comparison to before the intervention.

3. RESULTS

The implementation of Lean tools guided by the developed framework led to several measurable improvements:

- A 76,9% average reduction in risk levels across high-priority workstations as measured by the NTP 330 model (Marques et al., 2021).
- A 50% reduction in setup time in a workstation, which directly resulted in a doubling of production capacity in the finishing area.
- Increased production line balance, with better allocation of human and material resources.
- Reduced variability and fewer process interruptions, contributing to product quality stability.

Fig. 4. Before intervention

Fig. 5. After intervention

These results validate the core assumption that Lean tools, when strategically deployed within a structured framework, contribute positively not only to productivity but also to worker safety.

4. DISCUSSIONS AND FINAL CONCLUSIONS

The present study aimed to examine whether Lean tools, when implemented within a structured framework, could simultaneously enhance occupational safety and operational efficiency. The context of this study offered a suitable environment to explore these dual objectives due to the presence of high-risk manual operations and significant opportunities for productivity gains. By designing and applying a Lean-Based Safety Leadership Framework and operationalizing it through the SEVSM method, this research confirmed the viability of Lean tools as safety-enhancing mechanisms.

A fundamental intervention involved the integration of a Poka-Yoke system in the Ring Twister machines, which led to a reduction in ergonomic risks by 66%, physical risks by 87,5%, and mechanical risks by 40%. This initiative brought the workstations' risk score from 1300 to 300 points, a 76.9% reduction, clearly demonstrating its effectiveness. Additionally, setup time was reduced by 50% reflecting not only safety gains but also productivity improvements.

Another prominent measure was the duplication of the Ropemaking Completion workstation, which attended issues of psychological pressure due to high demand. While it did not directly affect physical risk, the psychological benefits that their psychological state influences their performance, and 50% reported feeling complete relief following the workstation duplication. This emphasizes the importance of psychological safety in the broader context of occupational safety.

Finally, a safety questionnaire distributed within the employees revealed that 76% of respondents believed the changes in the Ring Twister station reduced safety risks, and 63% felt a positive impact on their health and safety after the improvements. These perceptions validate the success of the actions implemented and confirm employee engagement with the safety enhancements.

A key outcome of the research was the demonstration that Lean implementation does not inherently jeopardize safety. This refutes a common misconception that the focus on productivity and waste elimination in Lean systems may neglect or undermine occupational health concerns. Rather, when Lean tools are selected and applied using safety-driven logic, they contribute directly to reducing risk. For instance, the SMED technique, typically used to reduce setup times, was shown to also reduce operator exposure to hazardous environments by minimizing interaction time. Similarly, 5S implementations improved ergonomics and layout, thus reducing physical strain and potential accident vectors.

The findings substantiate the variability of integrating safety into Lean methodologies without conflict. Traditionally, Lean has focused on efficiency, often sidelining safety as a secondary concern. However, this study demonstrates that with a strategic framework, Lean and safety can be symbiotic (Sá et al., 2021).

The SEVSM provided granular insights into both value-adding and risk-bearing activities, enabling targeted interventions (Marques et al., 2021). By adapting the Shingo Model and incorporating KBIs, the framework also guarantees that safety becomes embedded within the cultural fabric of the organization, rather than being a reactive measure (Bravo-Sanchez et al., 2018).

One essential factor in the framework's success was leadership involvement. The emphasis on leading with humility and respecting every individual, as promoted by the Shingo Model, creates a feedback-rich environment that supported sustainable change (Edgeman, 2018). The practical validation of this framework in a real industrial setting lends it credibility for replication in other contexts.
The role of leadership emerged as a critical success factor. Leadership that embodies humility, encourages feedback, and actively engages frontline workers in safety-related problem solving was pivotal to achieving sustainable improvements. These observations are in line with contemporary literature, which emphasizes the role of transformational and participatory leadership in shaping safety culture and achieving lasting change (Griffin & Hu, 2013; Bravo-Sanchez et al., 2018).
Moreover, the development of the SEVSM allowed the research team to visualize safety risks across the value stream, rather than treating them as isolated events. This systematic view of safety risk facilitated more holistic and coordinated interventions. The reduction of setup times and risk levels were not only outcomes but also feedback indicators that validated the mapping methodology.
From a methodological standpoint, the use of Action Research offered a practical and participatory framework that allowed continuous iteration and learning. It fostered collaboration between researchers, managers, and shop floor employees, which proved instrumental in overcoming resistance to change and aligning strategic objectives with operational realities.
However, it is important to acknowledge certain limitations of the study. First, the research was confined to a single industrial unit, which may constrain the generalizability of findings. The rope production processes, workforce composition, and organizational culture at the factory may differ from those of other industries. Second, while the framework produced encouraging short-term results, the sustainability of these improvements over the long term was not within the scope of this research. Additionally longitudinal studies world be required to determine if the behavioral and process changes observed are durable over time.
Future research directions may include applying the Lean-Based Safety Leadership Framework in different industrial sectors, particularly in higher-risk environments such as chemical manufacturing, construction, or logistics. Another avenue for exploration is the integration of digital tools such as real-time safety analytics, wearable sensors, or AI-based risk prediction systems to enhance the framework's responsiveness and scalability.
In conclusion, this study validates the central premise that Lean tools, when aligned with a robust, safety-orientated framework, can lead to tangible improvements in both productivity and workplace safety. It provides a tested model for industrial practitioners seeking to reconcile the imperatives of efficiency with the ethical and operational necessity of worker well-being. By moving safety to the core of Lean philosophy, rather than treating it as a compliance obligation, organizations. The Lean-Based Safety Leadership Framework offers a path toward this vision, anchored in cultural change, behavioral insight, and methodical execution.

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