

Lean Thinking and Workplace Safety: insights from two improvement projects

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Abstract

This article discusses the relationship between workplace safety and production management systems while analysing the empirical application of the lean thinking approach. In particular, this paper aims to determine whether the application of lean practices has beneficial effects not only on production efficiency but also on the health and safety of workers. The analysis is divided into two main stages: first, a review of the relevant literature was developed, followed by a case study analysis in an Italian metal casting company describing two continuous improvement projects from a workplace safety point of view. Both continuous improvement projects pursued the reduction of production interruptions and the elimination of defects, respectively. Research findings indicate health and safety conditions improvements after the implementation and application of various lean practices, especially by reducing risk exposure in the first project and improving the level of ergonomics in the second. This paper is of great interest for both researchers and practitioners since it suggests various possible relationships between the continuous improvement approach, provided by a practical application of the lean philosophy, and the improvement of workplace safety while fostering production efficiency.

Keywords

Lean production, Workplace safety, Human resources, Practices, Ergonomics.

1. Introduction

The international regulatory landscape encompasses several management systems that aim to optimize certain aspects of the production activities of firms such as the quality of processes (ISO 9001), respect for the environment (ISO 14001), energy management (ISO 50001) and occupational health and safety (ISO 45001).

In parallel with these renowned standards, various production models aimed to improve the efficiency of the industrial processes have been developed during the last decades. Among all, the most studied one in recent years is the Toyota Production System (TPS), also known as Lean Manufacturing (Garza-Reyes et al., 2018; Womack and Jones, 1996). This production model is characterized by five principles (define value, map the value stream, create flow, establish pull and seek perfection) and by the importance of reducing wasteful activities (muda), all this utilizing a wide variety of well-recognized practices and tools.

Besides, safety, health and environmental protection are concepts which are considered essential to sustainable growth (Taubitz, 2010). Two powerful concepts, lean and green, seem to be aligned (Dieste et al., 2019a), while the notion of safety is often missing in the analyses conducted. Moreover, stakeholders are progressively requesting the integration of safety practices in the daily operations of industrial firms.

Lean and occupational safety have occasionally been considered as opposites in previous researches. In particular, some practices related with the lean philosophy such as Just In Time were defined by various scholars as impediments for health and safety performance (Koukoulaki, 2014; Longoni et al., 2013). Furthermore, the logic of flexibility and the configuration of the production line achieved by the lean approach may impact the firm's risk assessment (Brown and O'Rourke, 2007). In contrast, other scholars such as Hafey (2017a) and Taubitz (2010) reveal that there may be an integrated vision of lean production techniques and safety management systems and consequently, both concepts share points in common.

Therefore, the aim of this paper is to explore whether a focus on reducing non-value-added activities based on lean thinking principles leads to better health and safety working conditions within the phases of a production process. This research will first develop a literature review to analyse previous works that have already addressed both lean and safety concepts and their relationships, providing a first vision of the topic from a theoretical point of view. Secondly, the evidences obtained from the literature will be evaluated through a case study developed in an Italian metal casting company that applies the lean thinking principles and practices since 2012. It is worth noting that the firm under analysis has a long experience in the application of lean practices, but at the same time, the company does not intentionally integrate safety activities within the lean application. Two continuous improvement projects aimed at increasing production and quality performance will be considered. These will be then related to both workers' health and safety risk scenarios using the premises contained in the Machinery Directive 2006/42/EC, the ISO standards and a method for measuring the ergonomic conditions.

This paper holds important managerial and theoretical implications, and therefore it is of interest for both practitioners and scholars as it provides insights about the links between the lean manufacturing paradigm and workplace safety. Additionally, this research identifies the positive effects on the employees' health and safety as a result of the implementation of two process improvement projects, using lean as a starting point.

2. Literature Review

This second section aims firstly to introduce the lean manufacturing concept, illustrating the essential elements and principles already addressed in the literature. Secondly, an overview of previous works regarding the study of the links between lean and safety will be provided.

2.1 The Lean Production Paradigm

Toyota's lean approach was developed as a result of the mass production crisis. During the early 1900s, Henry Ford and Frederick Taylor developed a new production system called "scientific", establishing various principles, tools and methodologies (Dieste and Panizzolo, 2019). However, the scientific method went into crisis in the 1970s when other manufacturers were able to provide much higher model variability (Panizzolo, 1998).

In this context, the Toyota Production System (TPS) developed by Taiichi Ohno was created. That new paradigm, due to the latest technologies, was able to synchronize production and assembly of components in a single

production line (Ohno, 1988). Currently, the lean production system is the most extended production paradigm (Womack and Jones, 1996). Its practices pursue the reduction of non-value-added activities in the entire firm processes, identifying seven types of waste, also known as muda (Ohno, 1988).

This philosophy is founded on the concept of “doing more with less”, and it is based in five principles: define value, map the value stream, create flow, establish pull and seek perfection (Womack and Jones, 1996). From the waste identification process, the employees can understand which operations add value, which operations do not add value and cannot be deleted (muda type I), and which operations do not add value and contribute to waste, these should be eliminated (muda type II).

Additionally, the lean paradigm is a multidimensional concept that is characterized by several practices aimed to accomplish waste reduction and value delivery objectives. The work developed by Shah and Ward (2003) establishes a categorization of these practices into four bundles; these are:

- Just In Time (JIT): includes practices related to production flow.
- Total Quality Management (TQM): involves practices related to continuous improvement and sustainability of quality products and processes.
- Total Productive Maintenance (TPM): comprises practices that aim to maximize equipment effectiveness through planned predictive and preventive maintenance and using maintenance optimization techniques.
- Human Resource Management (HRM): includes techniques such as job rotation, job design, formal training programs, work teams, problem-solving groups and employee involvement.

Concluding, the need to analyze the effects of lean considering newer views has emerged since its ability to increase firms’ operational efficiency has a worldwide recognized effect. In recent years, lean practices have evolved, and for instance, now lean practitioners have more soft tools such as operational development, coaching leadership, safety at work, competence planning, etc. These skills can be used to take advantage of further benefits from the application of lean practices. For example, Liker (2004) suggested that the adoption of a flow system allows for an improvement in process safety. Nevertheless, these concepts and their relationship with the lean paradigm have not yet been studied in depth (Dieste et al., 2019b).

2.2 The Relationship Between Lean Production and Workplace Safety

In recent years, various studies regarding the links between the lean paradigm and safety of workers have been developed. Moreover, several researchers have been focused on studying the implications and effects of the implementation of lean practices in the health and working conditions of the employees in different contexts. Opinions are generally divided between authors who associate lean with positive effects on health and safety conditions and those who believe that lean may lead to a worsening of health and safety at work.

The conclusions already obtained are based on different approaches; for example, Hafey (2017a) introduces an integrated vision of lean production techniques and safety management systems. Again, in another research, Hafey (2017b) highlights that a safety culture must not only comply with the law but must also go beyond applying the approaches of continuous improvement and workers’ involvement, typical of the lean paradigm. Andriulo et al. (2015) and Gnoni et al. (2013) propose the integration of lean management principles with occupational safety, more specifically, the second study presents a case study of a worldwide automotive supplier firm.

Brown and O’Rourke (2007) discuss how the lean manufacturing approach impacts the risk assessment related to new types of risk generated by the logic of flexibility and configuration of the production line. They also emphasize that a focus on worker participation in identifying and solving problems is critical for reducing negative impacts. The development of informed, empowered and active workers with the knowledge, skills, and opportunity to act in the workplace to eliminate or reduce hazards is vital for occupational safety in a lean production context.

Furthermore, Womack et al. (2009) carry out in their research a comparative study between two automotive companies, one of which features a much more advanced implementation of the lean approach. Authors compare the health and safety risks in 56 workstations to identify whether lean manufacturing can increase musculoskeletal disorders. The findings suggest that lean manufacturing does not necessarily increase workers’ risk for work-related musculoskeletal disorder injuries as long as crucial features of the system, such as process quality, are implemented.

More recently, Longoni et al. (2013) compare ten case studies from a lean thinking and safety joint perspective. Results demonstrate that the adoption of lean practices, or an overall lean philosophy implementation, have positive impacts on operational and health and safety performance. Nevertheless, the companies with the worst operational and health and safety performance were those that adopted JIT practices without human resource and prevention practices. Authors remark that both social and technical components of lean are essential to have positive operational and safety impacts from a lean point of view.

These results were partially confirmed by Koukoulaki in 2014. The author provides an extensive review of studies carried out in lean production environments in the last 20 years and concludes that there may exist negative effects regarding some lean manufacturing practices. More specifically, increased musculoskeletal risk symptoms were related to increases in work pace and lack of recovery time which were found in JIT systems.

In conclusion, the variability of the results already reported by the previous authors could be attributable to the contexts and the extent to which the analyses were carried out. Indeed, as was stated by Taubitz (2010) if incidents and diseases are considered waste within a context of corporate sustainability, the goal of reducing waste should also lead to an improvement of the safety conditions in any continuous improvement activity or project. Nevertheless, a clear identification of the empirical effects of lean practices on occupational safety is still needed, as limited empirical research has been conducted in this field.

3. Methodology

To understand whether the lean thinking approach is beneficial to the health and safety of workers, two improvement actions aimed only at increasing production and quality performance were selected. These were studied with particular focus on the health and safety of the employees of the company under study. Therefore, an exploratory case study was selected as a research method for this research paper (Yin, 2017).

The previous literature analysis has highlighted that the relationship between both lean manufacturing and workplace safety concepts has been weakly studied both theoretically and empirically. Thus, the single case study methodology is particularly appropriate for testing hypotheses in specific situations (Meredith, 1998) and generally to develop and extend theories (Voss et al., 2002).

During a six-month research timescale, multiple sources of evidence were used for the data collection phase (Barratt et al., 2011). Moreover, the selection of completed cases has permitted to avoid any influence in the decision-making process and to verify the effectiveness of the interventions on the overall efficiency index of the plant.

Consequently, the case study under analysis in this paper has been based on “Company SFT”, which is an important brand in the metal casting sector. This firm widely applies lean manufacturing production techniques without having systematically integrated them with its safety management system.

4. Case Study Analysis

4.1 Overview of Company SFT

The case study selected for this research is an Italian company founded in 1976, which is a leader in its sector. The firm’s main activity is the production and foundry of metal parts for automobiles. Over the years, the company has been constantly growing, and currently, Company SFT has more than 600 employees and a turnover of more than 100 million euros.

In 2007, Company SFT was acquired by an international group of companies. In total, the group has about 8000 employees and achieves a turnover of over 1.4 thousand million euros with a production capacity of over 21 million units of final product per year.

Finally, the firm integrates the entire design and production processes and the realization of the final product. Moreover, Company SFT holds important quality management certifications; has also achieved environmental management excellence according to ISO 14001 and is currently working to achieve ISO 50001 energy management standard. Both safety management and environmental protection are between the strategic objectives of Company SFT, however, are formally separated from the quality and continuous improvement (lean) projects that the firm has been applying for nearly ten years.

4.2 The Lean Approach of Company SFT

As was noted before, in 2012, Company SFT started its transformation towards the logic of lean production to enhance its competitiveness in an increasingly competitive and growing market, as well as to offer products and services that are aligned with customer needs.

Three employees form the Continuous Improvement Office, which is located in a raised position in the centre of the production area and has been designed to be easily transformed into a meeting room. However, even if the existence of a total implementation of the lean methods cannot be affirmed, several demonstrations of the extensive lean approach implementation can be observed throughout the production area of Company SFT.

For instance, elements related to the 5S method can be easily found throughout the plant, both with clear statements on the walls or with practical activities applied to the process. In addition, attempts to integrate quality and safety can be easily identified; these try to standardize the way information is communicated. For this aim, signs and information encoded through the One Point Lesson tool (OPL) are used. These techniques are consistent with the TPM principles. OPLs are grouped around the machines and are indicated in a panel representing the plan of the line. In particular, the OPLs are highlighted in different colours which show whether the activities indicated in the plan are cleaning (yellow), lubrication (green) or maintenance (blue) activities.

Another aspect that validates Company SFT's lean transformation process is the arrangement of "fast response meetings", where department heads meet for a brief update on quality, safety and project issues; the room does not purposely provide chairs because it must be used just for short information meetings. The space dedicated to these meetings is located within the production area and visually displays the company indicators related to efficiency, quality and safety.

Finally, in recent years the firm under analysis has achieved excellent results in terms of continuous improvement which have served as a reference for the rest of the companies of the group to which belongs. In particular, two relevant continuous improvement projects will be analysed in the following sections; these are the "minimal quantity lubrication project" and the "reduction of post-painting defects project".

4.3 The Minimal Quantity Lubrication Project

The first continuous improvement action described in this paper consists in the change of the lubrication technology used in various workplaces of the plant. More specifically, the project aimed to reduce cleaning downtime and consequently increase the availability of the plant.

During the continuous improvement activities developed by the firm, the head of department observed a high number of production stoppages. These were caused by the frequent cleaning needs of the roller conveyor and the working centre. At the same time, several "false positives" detected during the X-ray control were reported, these usually require interruptions to investigate the root causes and to perform the subsequent confirmation checks.

As a first step, the Continuous Improvement Office and the employees involved in the process developed a root cause analysis using the "5 Whys" method. Table 1 summarizes the result of the analysis to find the root cause.

Table 1. Summary of the "5 Whys" analysis for the minimal quantity lubrication project

	Numerous cleaning downtimes	Detection of several defects during X-ray analysis
Why?	Metal scraps accumulated on the roller	"False positives" detected during the X-ray control
Why?	Metal scraps transported by the product	Metal scraps stuck on the product's surface falsified the result
Why?	Scraps remain stuck from the processing phase	Scraps remain stuck from the processing phase
Why?	The lubricating fluid stuck the scraps to the product's surface	The lubricating fluid stuck the scraps to the product's surface

When a scrap that can distort the X-ray reading is identified, it must be removed. Then, the integrity of the product must be visually checked, and finally, the X-ray control must be repeated. A loss of 270 working hours a year from the “false scraps” identification issue and around 300 hours of extraordinary cleaning of the roller belt were estimated. Consequently, Company SFT’s approach was to replace the traditional lubrication method with a new technology that allows the firm to consume a minimal quantity of lubricant and therefore prevent the scraps from sticking to the product.

The minimal quantity of lubrication technology relies on the use of very small amounts of compressed air mixed with lubricant fluid. The emulsion is then applied as a spray. This avoids the problem of the scraps stuck to the product’s surface and permits a reduction in its consumption levels, which may vary from a few litres per hour to a few tens of millilitres per hour, with a relevant impact in purchasing and disposal costs. In addition, various benefits to the health and safety of workers which were not the aim of continuous improvement project were obtained. These derived from the reduction of waste and are summarized according to various criteria extracted from ISO 12100:2010 and ISO 23125:2010 standards in Table 2.

Table 2. Summary of the benefits obtained from the minimal lubrication project

	Parameter	Before	After
Economic measures	Overall equipment effectiveness	4% increase in availability	
	Payback of investment	4 months	
	Use of space	1000 litres tank and a tank for the disposal of wasted emulsion	Small tanks (various decilitres) set on the machine
Safety and environmental measures	Handling	1000 litres tank	5 litres tank
	Leak source	Pipeline crossing the production area	Tubes only inside the machine
	Biological risk	Mitigated by recirculation and cleaning	Eliminated
	Cleaning frequency	2 times per shift	Thorough cleaning twice a year
	Fluid presence	Possible fluid spill along the roller conveyor	Suction system, machine with cover cap
	Noise	Unchanged	
	Work environment	Contaminated (slippery) areas	Clean areas
	Disposal of emulsion	With specialized company	Eliminated

From a lean perspective, the implementation of the minimal technology has allowed significant economic benefits; the most evident is a 4-month payback of investment and a 4% increase in availability. Additionally, this case has led to an increase in safety conditions as a result of a direct production efficiency improvement. Safety improvements were not the final objective of the project, nonetheless, the benefits obtained comprised:

- Easier fluid management using small tanks. Forklifts are not anymore necessary for filling activities.
- Reduction (or elimination) of the procedures required to contain the fluid in the event of accidental leakage.
- Hazardous activities such as machine, workplace and roller conveyor cleaning were lessened.
- Decrease in the slippage risk by using small amounts of lubricant.
- Reduction of the biological risk due to the absence of lubricant use near the workstation.
- Elimination of lubricant disposal activities.

To conclude, a minor inconvenience was found by measuring the temperature of the tool. The readings showed an operating temperature of 30° Celsius, which is slightly higher than the traditional lubrication method. Nevertheless, this value does not represent a fire hazard.

4.4 The Reduction of Post-Painting Defects Project

The second improvement project involved the design of a new downstream quality control station for the painting process. In particular, the main objective of this action was to reduce discarded parts due to aesthetic defects, which needed to be downgraded or reworked after their detection.

After the mechanical processing, the product passes to the painting area and, before the final palletizing, each product is inspected individually to detect any defect. This inspection process usually involves around 400-500 pieces per hour divided into four operators. Each of the workers manually grabs the piece that is delivered to them by a conveyor belt, then moves it to analyse the various surfaces and eventually highlights non-compliant areas to send them to later processing. This issue had an incidence of 19% of the pieces and therefore required a project for process improvement. To understand the root causes of this problem, the “5 Whys” method was utilized as in the first project (see Table 3).

Table 3. Summary of the “5 Whys” analysis for the post-painting defects project

	Scratches in the inner surface of the piece
Why?	Scratches due to friction between the piece and the control station
Why?	Handling problems at the final unload, operators drag the piece
Why?	In the middle of the control station there is a gap, during the control process the piece enters in it damaging itself
Why?	Presence of scratches on the gap surface due to rotation of the piece

As shown in Table 3, the handling of the pieces during the control process produced scratches in the surface of the workbench (in plastic material) that scratched the product during the subsequent manipulations. Therefore, it was decided to design a new workbench for the control station, redesigning it to avoid movements that could damage the surface and following pieces.

The design of the new quality control station was mainly developed from an ergonomic point of view to reduce the product movements on the control bench, especially rotations. The new station is equipped with a rotating top with a hole containing two rollers (see Figure 1). This configuration allows the rotation of the product both in lying and vertical positions. Also, between the two rollers, there is a gap that will enable the discharge of the caps that are inserted into the holes for the fastening screws. These caps prevent the entry of paint inside the screw holes.



Figure 1. Control quality bench before and after improvement

During the Kaizen events developed, the Continuous Improvement Office took into consideration workers’ opinions. These suggested the levelling of the workload to avoid disparity of workload for the operator in the first station of the line. The automation logic was usually sending the product to the second control station only when the first one was not available, with a significant disparity between both stations. This request was solved with the installation of photocells that assess the queues at each control station to then send the pieces to the four workstations in a balanced manner.

The station was then restructured in the perspective of the 5S methodology, making more easily accessible all the necessary equipment, such as the stamp and ink pad for the identification of the quality control operator, marker to identify defective areas and compressed air for product cleaning.

This approach has allowed a quick reduction of product defects, going from 19% to almost 0% in just a few weeks. Moreover, various operators stressed the improvements accomplished in both ergonomic and working conditions. Therefore, in order to analyse the ergonomic conditions before and after the transformation and then to assess the health benefits for workers, the Occupational Repetitive Actions (OCRA) index was calculated (Occhipinti, 1998).

This method is generally used for ergonomic evaluation and is linked to the ISO 11228-3; this standard is related to the handling of loads at high frequency.

The ISO 11228-3 standard establishes in the first phase of risk detection various factors that help to determine the potential effect on workers' health such as repetitions, vibrations, recovery periods, etc. Moreover, the standard provides two levels of risk assessment. The first, based on a questionnaire present in the standard itself, through which a risk profile divided into three levels can be obtained: green or without risk, yellow or low risk, and red or high risk. The second risk assessment level, which is more complex, is used when the first and simpler assessment shows a yellow or red level of risk, or when more in-depth analysis is required. For its calculation, the following formulas were used:

$$OCRA = \frac{A_e}{A_r} = \frac{\text{total number of technical actions actually performed}}{\text{total number of recommended technical actions}}$$

in which:

$$A_e = f \times t \quad \text{and} \quad f = \frac{n_{TC} \times 60}{t_{TC}}$$

and:

$$A_r = (k_F \times F_M \times P_M \times Re_M \times Ad_M \times D) \times D_M \times R_{C_M}$$

The determination of the coefficients permits the calculation of the total number of technical actions performed and the number of recommended technical actions, both necessary to define the OCRA index (Occhipinti, 1998). Table 4 summarizes the parameters for the calculation of the OCRA index in the two situations.

Table 4. Summary of results for the calculation of the OCRA index

Parameter		Before improvement		After improvement	
		Left arm	Right arm	Left arm	Right arm
Number of technical actions in the cycle	n_{TC}	11	14	7	12
Cycle time	t_{TC}	30	30	30	30
Frequency of technical actions	f	22	28	14	24
Total number of technical actions actually performed	A_e	4950	6300	3150	5400
Frequency constant	k_F	30	30	30	30
Force multiplier	F_M	0.86	0.88	1.00	0.98
Posture multiplier	P_M	0.7	1.0	1.0	1.0
Repetitiveness multiplier	Re_M	1.0	1.0	1.0	1.0
Additional elements multiplier	Ad_M	0.90	0.90	0.90	0.90
Duration of the repetitive tasks (min)	D	225	225	225	225
Partial reference number of technical actions in the shift	n_{RPA}	3657	3635	6075	5954
Duration multiplier	D_M	1.5	1.5	1.5	1.5
Recovery multiplier	R_{C_M}	0.45	0.45	0.45	0.45
Total number of recommended technical actions	A_r	2469	2454	4101	4019
OCRA index		2.01	2.57	0.77	1.34

As can be seen in Table 4, the reduction of the OCRA index is linked to a two-fold effect: on the one hand, the reduction in the number of actions achieved (Ae) through the simplification of the actions carried out by the installation of the rotating top and the cylinders, these allow the product to move without any effort; on the other hand, the increase in technical reference actions (Ar) through the reduction of applied efforts and an improved posture of the left arm. Once the OCRA indexes have been calculated, these can be classified in the different risk zones depending on their value (see Table 5).

Table 5. Criteria for risk assessment with the OCRA index

Zone	OCRA index	Risk level
Green	≤ 2.2	Without risk
Yellow	$2.2 < \text{Index} \leq 3.5$	Low risk
Red	> 3.5	High risk

A summary of the results obtained is shown in Figure 2, where the horizontal line represents the limit of the green zone (without risk). Above this limit, in the yellow and red zones, risk mitigation activities are required, or in the worst cases, it is necessary to redesign activities and workstations.

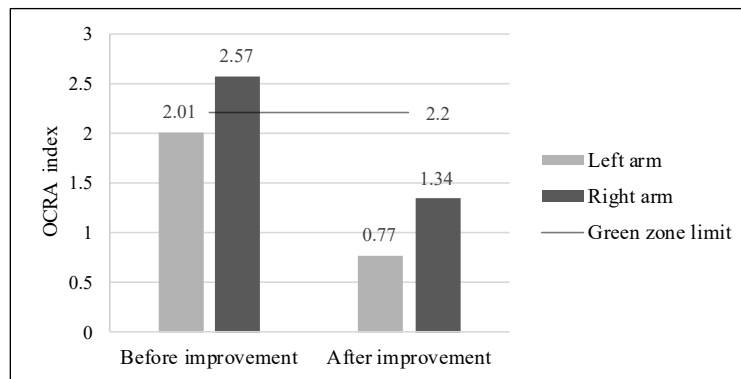


Figure 2. OCRA indexes in both scenarios

Concluding, the improvement project introduced also had beneficial effects on the level of ergonomics. The modifications launched had an impact in various aspects:

- A reduction of the elementary actions performed by each arm during the working cycle, which is more noticeable for the left arm. A handling reduction implicates the possibility of performing moves with the most comfortable arm that, since it is less tired, it also absorbs activities that could be deferred to the left arm.
- Effort reduction due to the introduction of the rotating system.
- An improvement in the posture coefficient, mainly related to the pronation of the elbow which, with the rotating plane now can be avoided.

Therefore, and as in the first case, an improvement activity launched for productive purposes has produced a benefit to the health of workers.

5. Concluding Remarks

The present study considers the possibility of obtaining safety improvements enabled by the application of a production management system; in this case, the lean approach developed by Toyota. In particular, this article aimed to determine whether an application of lean manufacturing techniques had beneficial effects not only on productivity performance but also on the health and safety of workers.

The literature review analysis has shown conflicting views regarding the effect of lean thinking on the health and safety of workers. Various authors, mainly from the operations management area, believe that the application of lean manufacturing practices can improve the working conditions of the employees; other authors, primarily from the area of industrial sociology and health areas, believe that there may exist adverse effects related to lean.

The empirical analyses presented through the case study in Company SFT, have demonstrated a positive effect on health and safety as a result of the lean improvement activities; however, the results cannot be considered statistically significant to draw more general conclusions. This paper is particularly interesting since the implementation of a lean improvement project has enabled the transition from a traditional lubrication method to a minimal lubrication method, and it has allowed an improvement of the 4% of the global efficiency index (OEE) with a payback of investment of four months. Additionally, the analysis carried in the second improvement project with a lean perspective of the post-painting defects has led to a complete redefinition of the workstation with a focus on maximizing the value-added activities carried out by the operator. More specifically, the root causes analyses have permitted the introduction of simple but effective modifications, and the participation of workers has enabled the balance of the workload between the different control stations operating at the same line. Thus, both lean applications have led to remarkable benefits regarding the risk exposure and ergonomics of the workers involved.

An analysis of this scale requires an in-depth knowledge of both lean thinking and safety in the workplace, understood as requirements and risk assessment techniques. This study encountered a limitation since already completed projects were used, making it difficult in some situations to obtain information with a very high degree of accuracy. Hence, a future research direction could be the follow-up of a lean improvement project to understand its effects on the level of security for employees before, during and after its implementation. Moreover, it should be considered that the whole analysis was limited to the manufacturing sector. Therefore, there are several research opportunities in other areas, such as construction, healthcare, etc. that could be reviewed according to their specific regulatory requirements.

In other words, lean manufacturing offers a range of practices and tools that need to be used in the right way and at the right time; the balance in the use of these tools is not established a priori but should be determined on a case-by-case basis depending on the company's vision and specific characteristics. In contrast, the application of these instruments without having grasped the lean philosophy and without adapting them to each case will hardly allow the achievement of effective results.

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Biographies

Marcos Dieste is a Postdoctoral Research Fellow at the Department of Management Engineering of the University of Padova (Italy). He received his Ph.D. in Management Engineering from the University of Padova, Master's degree in Management Engineering from the University of Zaragoza (Spain), and his bachelor's degree in Business Administration and Management from the University of Zaragoza. After some years working in industrial, consultancy and managerial environments, Dieste is currently researching in diverse fields such as strategy and operations management, sustainability, climate change, logistics, supply chain, tourism and service management.

Alessandro Baseggio got his Master's degree in Materials Engineering at the University of Padova (Italy) with a thesis about induction heating, in cooperation with Leibniz Universität Hannover (Germany). Shortly, he started collaborating with companies producing industrial machinery. In 2011, in cooperation with a spin-off of the University of Padova, he has contributed to the development of a patented technology to apply bituminous membranes with induction heating technology. This concept was ranked on the top 10 projects at Innovation Award 2015 (a contest in the frame of Batimat 2015 exhibition in Paris). In 2018, Alessandro got a second Master's degree in Safety Engineering at the University of Padova with a dissertation about the integration of Lean Production System and Safety Management System. The thesis has been awarded by Italian Safety Professionals Association. Currently he is actively involved in industrial projects with international organizations regarding quality, health, safety and environment.

Roberto Panizzolo is Associate Professor of Operations Management and Lean Manufacturing at the University of Padova (Italy). He got his Doctorate degree in Industrial Engineering at the University of Padova. His research activity has led to the publication of more than 160 works in national and international peer-reviewed journals, conference proceedings and books. Additionally, Professor Panizzolo has an experience of more than 25 years in corporate reorganization projects, aimed at improving the operational performance of companies by redesigning their production and logistics systems.

Stefano Biazzo is Associate Professor of Innovation Management at the University of Padova (Italy). He got his Doctorate in Management and Organization Design at the University of Padova. On issues of product innovation and organizational innovation, his research activity has led to the publication of more than 80 works in national and international peer-reviewed journals, conference proceedings and books. Additionally, Professor Biazzo has an experience of more than 20 years in organizational change projects, aimed at developing and disseminate concepts, methodologies and tools to enhance firms' innovation performance and continuous improvement capability.