INTERFACE TECNOLÓGICA

IMPROVING THE ECONOMIC AND ENVIRONMENTAL SUSTAINABILITY OF PAINTING AND GLUEING OPERATIONS IN A LUXURY LEATHER GOODS INDUSTRY USING DMAIC METHODOLOGY – a case study

Carlos Roberto Regattieri - regattieri14@gmail.com
Technological College of Taquaritinga, Centro Paula Souza, Taquaritinga, São Paulo, Brazil

FJG Silva
CIDEM, ISEP – Escola Superior de Engenharia, Politécnico do Porto, Portugal

DOI: 10.31510/infa.v22i1.2027
Data de submissão: 19/09/2024
Data do aceite: 26/06/2025
Data da publicação: 30/06/2025

ABSTRACT

The luxury goods sector is distinguished by a distinctive production framework that prioritizes craftsmanship, exclusivity, and differentiation, thereby establishing elevated consumer expectations for products that are devoid of defects, exhibit durability, and demonstrate sustainability. In the year 2019, the worldwide luxury market attained a valuation of 281 billion euros. Nonetheless, these enterprises are not immune to operational challenges. This investigation sought to enhance the internal logistics and processes of these organizations by examining methodologies for the supply of materials to production lines and conducting a thorough analysis of production processes, specifically focusing on the utilization and management of filters that facilitate leather gluing and painting tasks. The filters play a crucial role in absorbing excess adhesive or paint from the edges of the products, effectively preventing the formation of adhesive or paint accumulations. The application of the DMAIC methodology in conjunction with Lean tools (Lean Six Sigma) facilitated the optimization of production line supply, resulting in a decrease in errors associated with material distribution, modifications in the products employed to assist gluing and painting operations, a reduction in warehouse inventories, minimized operator movement, and a significant decrease in waste directed to landfills. Following the execution of all proposed enhancements, anticipated annual savings exceeding €100,000 and an augmentation of 77.73% in usable warehouse space are projected. Furthermore, the organization’s environmental footprint has been alleviated, as evidenced by an 88.72% reduction in the volume of waste dispatched to landfills.

Keywords: DMAIC, Continuous improvement, Sustainability, Warehouse, Production improvement.

1. Introduction

The luxury goods market is distinguished by a distinctive production framework, wherein expertise, exclusivity, and differentiation are pivotal for its advancement. These attributes inadvertently cultivate elevated expectations among final consumers, who necessitate flawless, durable, and sustainable products. Consequently, it is imperative to perpetually enhance production methodologies and incessantly pursue increasingly sustainable alternatives. The global luxury leather goods market was valued at USD 42,743.74 million in 2021, with projections indicating that the market is anticipated to attain USD 60,633.19 million by 2031, demonstrating a Compound Annual Growth Rate (CAGR) of 3.56% throughout the projected period (CHRISTODOULIDES; WIEDMANN, 2022; MORGAN, 2023).

These enterprises recognize the imperative to enhance their operational procedures and internal logistics. Consequently, it is essential to formulate methodologies that facilitate the identification of issues and their resolute mitigation. The objective of this project was to conceptualize and evaluate this methodology in relation to this specific sector. Therefore, the primary aim of the investigation was to refine the internal logistics of companies producing industrial luxury goods, where quality and manual labor are prioritized, by examining various material supply techniques and scrutinizing the production processes across different lines, with the intent to reduce waste and enhance environmental sustainability (SILVA; GOUVEIA, 2020). To substantiate the developed methodology, a case study was chosen that would target the modification of the filter management system employed in the gluing and coloring operations, thereby preventing the ongoing disposal of these contaminated materials in landfills. It was anticipated that, through the effective redesign of the supply chain method, the incidence of material discrepancies between workstations, inventory levels in the warehouse, the movements of operators, the utilization of filters, and the volume of waste directed to landfills would be diminished, thereby augmenting the economic and environmental sustainability of the process.

2. Literature review

Irrespective of the industry in which they function, organizations are compelled to continuously diminish expenditures, while simultaneously enhancing the sustainability of materials, minimizing waste, and elevating product quality (VOORTHUYSEN; OLSEN; LANGLEY; LIPSKI; SUBRAMANIAN, 2017). Moreover, it is imperative that they execute orders within a specified timeframe. Consequently, enterprises must demonstrate concern and dedication towards their systems of continuous improvement (ROSA; SILVA, 2017). The realization of continuous improvement can be facilitated through the implementation of automation (MOREIRA; SILVA; CAMPILO, 2017), management instruments, or a synergistic combination of both (ARAUJO; SILVA; CAMPILO; MATOS, 2017). The luxury leather goods sector is similarly affected, confronting various ethical issues associated with the utilization of animal hides (KLERK; KEARNS; REDWOOD, 2019). Production methodologies are particularly susceptible to the accumulation of waste concerning both cycle duration and material resources (PRASAD, S.; KHANDUJA, D.; SHARMA, S.K., 2018). Despite the increasing design of processes aimed at waste reduction, this objective is typically fulfilled over the duration of the projects, thereby alleviating various forms of waste. The Lean philosophy is fundamentally oriented towards the maximal elimination of waste (BALL, P.D.; ROBERTS, S.; NATALICCHIO, A.; SCORZAFAVE, C., 2011), having essentially delineated seven distinct categories of waste (EL-NAMROUTY, K.A.; ABUSHAABAN, M.S., 2013), to which an additional category was incorporated, which pertains to the underutilization of employee capabilities. Although the Lean philosophy was formulated based on the renowned Toyota Production System, which sought to address industrial challenges in the aftermath of World War II (DIAS, P.; SILVA, F.J.G.; CAMPILHO, R.; FERREIRA, L.P.; SANTOS, T., 2019), Bill Smith of Motorola established a methodology aimed at the continuous enhancement of production systems, thereby minimizing variability in production outcomes and significantly reducing quality-related issues (which are also a source of waste) (MILEHAM, T., 2019; MURMURA, F.; BRAVI, L.; MUSSO, F.; MOSCISZKO, A., 2021). Given that both methodologies converge upon the systematic resolution of challenges and the minimization of waste, the Lean Six Sigma framework emerged, also referred to as Lean DMAIC, which has become a widely adopted strategy for waste mitigation. Two principal components of the Six Sigma methodology are particularly noteworthy: DMAIC (Define, Measure, Analyze, Improve, and Control) and DMADV (Define, Measure, Analyze, Design, and Verify). The former emphasizes the enhancement of pre-existing processes (RONG, K.; DING, H.; SONG, B.; GAO, J.; TANG, J., 2021), while the latter is concerned with the design of novel manufacturing processes (BAPTISTA, A.; SILVA, F.J.G.; CAMPILHO, R.D.S.G.; FERREIRA, S.; PINTO, G., 2020). Lean Six Sigma has exhibited remarkable efficacy in addressing intricate problems, even within advanced sectors (AYENI, P.; BAINES, T.; LIGHTFOOT, H.; BALL, P., 2011). Below, several cases are elucidated wherein the Six Sigma methodology, in conjunction with Lean tools, yielded highly favorable outcomes, enhancing quality and diminishing preliminary waste. Due to the considerable discrepancies noted in the dimensions of two critical components utilized in the tire manufacturing sector for the automotive industry, specifically the tread and the sidewall, Costa et al. (COSTA, T.; SILVA, F.J.G.; FERREIRA, L.P., 2017) employed the DMAIC methodology to diminish the scrap produced during their fabrication processes. Consequently, it was feasible to achieve a reduction in the scrap of extruded rubber products by 0.89%, which translated into an annual financial saving of €165,000 and a substantial decrease in the environmental impact associated with materials that are challenging to recycle. Pereira et al. (PEREIRA, M.T.; BENTO, M.I.; FERREIRA, L.P.; SÁ, J.C.; SILVA, F.J.G.; BAPTISTA, A., 2020) applied the DMADV framework to assess customer satisfaction within the developmental processes of components for the automotive industry, with the objective of attaining complete satisfaction. Metrics such as Quality Control and Time to Market were scrupulously monitored, facilitating the identification of elements that contributed to challenges in the innovation of new products, thus fulfilling the criteria established by clientele. Based on the issues identified, it became increasingly feasible to substitute or modify processes to effectively realize the desired outcomes. The enhancements proposed and executed lessened delays and quality-related complications during the pre-series development phase. A parallel investigation into customer satisfaction was previously undertaken by Behara et al. utilizing a Six Sigma framework. While the aforementioned instances may present medium-level complexities for resolution, (NONTHALEERAK, P.; HENDRY, L., 2008) indicated that Six Sigma methodologies are readily adaptable to more intricate situations. The integration of Lean and Six Sigma tools has also been employed within the service sector, particularly in notably complex scenarios, such as aircraft maintenance, enhancing problem detection, repair operations, and quality improvement protocols, thereby reducing customer grievances. (AYENI, P.; BAINES, T.; LIGHTFOOT, H.; BALL, P., 2011) conducted a comprehensive literature review centered on aeronautical maintenance and the potential contributions of these tools in enhancing processes, eradicating waste, and elevating service quality.

3. Methods

This research is categorized as a descriptive, exploratory, qualitative, and quantitative investigation grounded in Lean Six Sigma principles. The DMAIC framework serves as a systematic problem-solving methodology adept at integrating Six Sigma into pre-existing operational processes. The instruments employed within the DMAIC framework encompass control charts, histograms, Pareto diagrams, scatter plots, flowcharts, Ishikawa diagrams, and check sheets (CHANDRASEKARAN, R.; CAMPILHO, R.D.S.G.; SILVA, F.J.G., 2019). Additionally, other Lean methodologies may be evaluated for their efficacy in addressing challenges, particularly in light of the volume and quality of the available data, along with the specific focus of the research endeavor. Consequently, the DMAIC framework will be adhered to in this investigation, supplemented by various Lean tools such as the Ishikawa diagram, the 5W2H analysis, and the 5S methodology.

3.1 Define

It is at this stage that the problem needs to be defined, which consists of reducing the area occupied by the filters used in the gluing and coloring processes, due to the need to increase the warehouse area to receive new raw materials and finished products. As a strategy to resolve this, it will be necessary to measure consumption, consumption rate, and possible standardization reducing the number of references in use. The problems found, after thorough observation, make it possible to outline the desired routes and objectives for improving the process, as shown in Table 1.

Table 1. Identified problems and proposed solutions

Item	Problem	Context	Main goal
Filters used as support for gluing and colouring operations	Large area occupied.	Companies are constantly growing which requires a larger area in the warehouse to receive new raw materials and finished products.	Reduction of current space by 20%.
	Measure the filters consumption.	Identify the quantity and type of each filter used in gluing/colouring.	Identify the type that uses the most storage area, comparing the consumption of each filter model.
	Problems root-causes identification.	Lack of a routine for replacing side filters in the gluing process	Improve the production process through the DMAIC methodology.
		Poor purchasing process.	
		Lack of control over filter consumption in the gluing and coloring processes.	
		Failure to comply with filter change routines.	
		Incorrect filters use.	

Source: Author (2024)

3.2 Measure

In this phase, the measurable factors are calculated and measured, and the variability is qualified. The consumption of the filters were collected for three months. The filters references that contributed the most to unavailable warehouse area were: C00278, C00275 and E14123. Values collected by the workers are shown in Table 2.

For the coloring process, due to the difficulty in identifying the filters references used in these coloring booths, labels with specific references were developed. The amount consumed and the replacement periods for side filters are shown in Table 3.

Table 2: Change period for side filters and carpet

Reference	Quantity consumed/month	Average exchange period
E14125	21 units	Each 3 weeks
E14126	2 units	
E14127	2 units	
C00275	2 units	Monthly
C00279	16 units	Each 3 months

Source: Author (2024)

Table 3: Change period for side filters and carpet

Reference	Pallets weekly stock	Pallets weekly consumption
C00278	200 units	Between 5 and 6
E14123	9 units	Between 1 and 2
E13103	6 units	Less than 1
E13107	7 units	Less than 2
E13105	2 units	Less than 3
C00275	2 units	2

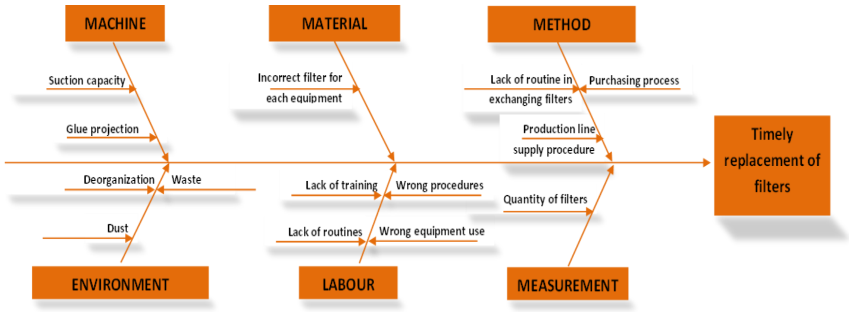
Source: Author (2024)

It was possible to observe that the C00275 filter occupies a large area due to its size, and not due to excess of stock, therefore, its analysis is not justified.

3.3 Analyze

Information from this analysis can help determine the sources of variability and unsatisfactory performance, which can be very useful in improving processes. An Ishikawa diagram was created (Figure 1) bringing together the main causes related to the large area occupied by the filters in the warehouse.

Figure 1: Ishikawa's analysis regarding the problems around the timely exchange of filters



Source: Author (2024)

It was possible to notice that there is a large discrepancy between the actual production consumption and the stock in the warehouse. Therefore, the filter purchasing process is not adjusted to your consumption, causing excess stock in the warehouse. A factor that contributes to stock instability is the lack of standardization in the use of filters in coloring booths, with the same equipment having different types of filters.

The standardization of filters is considered a necessity and priority, with a view to ensuring stable consumption per type of filter on the shopfloor. Although there is no excess stock in relation to the side filters, inherent to the gluing process (E14125, E14126 and E14127), there is no periodicity for their replacement. On average, they are replaced every three weeks, depending on the request to the warehouse by the team manager. This factor can generate instability in stock, which is why it needs to be corrected. Type A staining benches use two C000278 filters on top, which adapt to the size of the bench. However, this equipment has a roller filter holder, facilitating the replacement process. This filter must be inserted in the purchase process. Additionally, there is a C000278 filter inside the equipment, cut to fill the available space. Silpar model coloring booths also require filters to be adapted to the equipment by cutting them. Actions must be implemented to minimize replacement time and eliminate the cutting process, contributing to increased productivity and reduced waste. This also applies to the side filters of glue dispensing robots for certain by-products that need to be glued.

The duration of the filter replacement process, obtained by monitoring the two shifts and timing the process for four weeks, are described in Table 4.

Table 4: Time spent in changing filters

Equipment	Requires cutting process	Average time to exchange filters (min)
Colouring bench A	Yes	16
Colouring bench B	---	12
Colouring booth Silpar	Yes	7
Colouring booth A	---	4
Carpet roll (side filters)	Yes	12
Gluing robot 620 or 249 (side filters)	---	8

Source: Author (2024)

Filter replacement times are actions that do not add value to the production process, promoting a cause and effect, shown in Table 5, and which will be addressed in the improve phase.

Table 5: Actions without value-added, root-causes and corresponding effects

Actions without value-added	Causes	Effects
Incorrect use of filters	Purchase process unsuitable regarding the consumption.	Need for a larger warehouse stock area.
Lack of information about the correct filter to be used in the equipment	Unnecessary employee travel to the intermediary shopfloor warehouse.	Loss of Productivity.
Failure to comply with filter replacements and failure to observe the technical specifications for programming glue robots	Lack of information on filters suitable for each piece of equipment and filter replacement routines. Incorrect entry of glue robot programming coordinates. Non-optimization of templates in gluing processes.	Product quality issues. Employee health issues (inadequate filtering). Equipment degradation. Increased filter consumption.

Source: Author (2024)

3.4 Improve

In the improvement phase (Improve), the actions to be adopted are defined to make the process more effective. It will also be necessary to ensure that necessary improvements and adjustments are made to actions that do not add value, through the implementation of the proposed changes.

3.4.1 Brainstorming and critical analysis of improvement proposals

To define the proposed improvements, the 5W2H tool was adapted to 3W1H – What, Why, When and How. As the Where and Who actions take place on the shopfloor, the How Much action will be detailed separately. Table 6 below demonstrates the 3W1H table.

Table 6: Frame 3W1H

Item	What	Why	When	How
1	Identification of suitable filters for each equipment	Lack of stander filters for each equipment/Quality problems.	January 2024	Acquisition of filters with exact dimensions.
2	Defining a filter replacement frequency	Colouring equipment has a defined periodicity, which is not followed. The side glue filters do not have defined periodicity.	January to February 2024	Colouring Filters: creating a defined routine / Glue Filters: identifying durability of use.
3	Replacing the most expensive filters	Decrease replacement costs	January to February 2024	
4	Replacing the filters with the highest consumption	Need to reduce the area occupied in the Warehouse	February to April 2024	Creation of a facilitating and reusable filter changing device
5	Adjusting the purchasing process to the Atelier's needs	Reduce the warehouse stock area for new raw materials and products	March to April 2024	Creation of kit systems for inventory management and material flow control
6	Organization of improvements in the area related to the gluing process	Unnecessary movement and lack of ordering of materials used	May 2024	Application of the 5S tool
7	Training and awareness of workers for the filter replacement process	Non-observance of the filter exchange process by workers	May 2024	Training and awareness regarding filter changes and environmental impacts

Source: Author (2024)

3.5 Control

In the Control phase, the objective is to ensure that the proposed improvements are sustained to increase reliability and plan for possible corrections or setbacks. New measurements were made in order to validate the impact of the improvements implemented. After implementing an appropriate replacement routine, and standardizing the filters in each piece of equipment, it was possible to create a simpler and more controlled process, facilitating stock management in the warehouse. Regarding the side filters of the glue robots, E14125, E14126 and E141277, the replacement with a more economical solution allowed significant weekly savings. The fortnightly filters, using the supply station in production, were adapted to the KIT system, as were the side filters of the gluing robots, which were more expensive. With the implementation of this system, it was possible to reduce the occupied space from 17.5 m² to 2.75 m², representing a decrease of 26.81% in the area occupied in the warehouse.

4. Results and Discussion

The Lean Six Sigma methodology, with the DMAIC tool – Define, Measure, Analyze, Improve and Control, resulted in process improvements, greater employee engagement and more defined action plans for teams Trubetskaya A, Ryan A, Powell DJ, Moore C (2024). Lean methodology is increasingly being implemented to manage such challenges because it improves a company's responsiveness to changing customer demands while at the same time optimizing underlying operational processes Knapić V, Rusjan B, Božič K (2023). The results achieved presented an estimated annual saving of €42,193.84 with the implemented measures, with a forecast of €105,207 due to the adoption of the plate system and the complete elimination of drawer filters. Another result was the reduction in the area occupied in the warehouse from 17.5 m2 to 2.75 m2. This will increase the useful area of the warehouse by 77.73% and reduce the organization's environmental impact by reducing waste produced by 88.72%. After implementing all improvement suggestions, annual savings of more than €100,000 are expected and an increase of 77.73% in usable warehouse area. The organization's environmental impact was also mitigated, with a reduction in the amount of waste sent to landfills by 88.72%.

5. Conclusions

The combined use of Lean tools such as the Ishikawa diagram, 5W2H and 5S allowed, following the six-sigma methodology, the use and management of the use of filters to support the gluing and painting operations of leather used in the production of leather goods. luxury was significantly improved, resulting in noteworthy operational improvements. It can therefore be seen that the combined use of Lean tools and six-sigma methodology, normally known as Lean Six. -Sigma, constitutes a perfectly suitable strategy for approaching and improving the functioning of production lines, also regarding articles. luxury leather. The case study reported here, despite being quite unique, can constitute a roadmap for the joint application of these tools and methodologies in other sectors, overcoming some existing doubts.

References

Araújo, W.F.S., Silva, F.J.G., Campilho, R., & Matos, J.A. (2017). **Manufacturing cushions and suspension mats for vehicle seats: A novel cell concept**. *Journal of Advanced Manufacturing Technology*, 90, 1539-1545. https://doi.org/10.1007/s00170-016-9475-6

Ayeni, P., Baines, T., Lightfoot, H., & Ball, P. (2011**). State-of-the-art of 'Lean' in the aviation maintenance, repair, and overhaul industry**. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, 225(11), 2108-2123. https://doi.org/10.1177/0954405411407122

Ball, P.D., Roberts, S., Natalicchio, A., & Scorzafave, C. (2011). **Modelling production ramp-up of engineering products**. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, 225(6), 959-971. https://doi.org/10.1177/09544054JEM2071

Baptista, A., Silva, F.J.G., Campilho, R.D.S.G., Ferreira, S., & Pinto, G. (2020). **Applying DMADV on the industrialization of updated components in the automotive sector: A case study**. *Procedia Manufacturing*, 51, 1332–1339. https://doi.org/10.1016/j.promfg.2020.10.186

Behara, R.S., Fontenot, G.F., & Gresham, A. (1995). **Customer satisfaction measurement and analysis using six sigma**. *International Journal of Quality & Reliability Management*, 12(3), 9-18. https://doi.org/10.1108/02656719510084745

Chandrasekaran, R., Campilho, R.D.S.G., & Silva, F.J.G. (2019). **Reduction of scrap percentage of cast parts by optimizing the process parameters**. *Procedia Manufacturing*, 38, 1050-1057. https://doi.org/10.1016/j.promfg.2020.01.191

Christodoulides, G., & Wiedmann, K.-P. (2022). **A roadmap and future research agenda for luxury marketing and branding research**. *Journal of Product & Brand Management*, 31(3), 341-350. https://doi.org/10.1108/JPBM-01-2022-3815

Costa, T., Silva, F.J.G., & Ferreira, L.P. (2017). **Improve the extrusion process in tire production using Six Sigma methodology**. *Procedia Manufacturing*, 13, 1104-1111. https://doi.org/10.1016/j.promfg.2017.09.171

De Klerk, H.M., Kearns, M., & Redwood, M. (2019). **Controversial fashion, ethical concerns and environmentally significant behaviour: The case of the leather industry**. *International Journal of Retail & Distribution Management*, 47(1), 19-38. https://doi.org/10.1108/IJRDM-05-2017-0106

Dias, P., Silva, F.J.G., Campilho, R., Ferreira, L.P., & Santos, T. (2019). **Analysis and improvement of an assembly line in the automotive industry**. *Procedia Manufacturing*, 38, 1444-1452. https://doi.org/10.1016/j.promfg.2020.01.143

El-Namrouty, K.A., & AbuShaaban, M.S. (2013). **Seven wastes elimination targeted by lean manufacturing: Case study 'Gaza strip manufacturing firms'**. *International Journal of Finance and Management Economics*, 1(2), 68-80. https://doi.org/10.11648/j.ijefm.20130102.12

Knapić, V., Rusjan, B., & Božič, K. (2023). **Importance of first-line employees in lean implementation in SMEs: A systematic literature review**. *International Journal of Lean Six Sigma*, 14(2), 277-308. https://doi.org/10.1108/IJLSS-08-2021-0141

Mileham, T. (2019). **Essentials of Lean Six Sigma: Book review**. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, 221(8), 1375. https://doi.org/10.1177/095440540722100801

Mistry, K.P., Jaggers, J., Lodge, A.J., et al. (2008). **Using Six Sigma® methodology to improve handoff communication in high-risk patients**. In *Advances in Patient Safety: New Directions and Alternative Approaches* (Vol. 3: Performance and Tools). Rockville, MD: Agency for Healthcare Research and Quality (US). PMID: 21249919

Moreira, B., Gouveia, R.M., Silva, F.J.G., & Campilho, R. (2017). **A novel concept of production and assembly processes integration**. *Procedia Manufacturing*, 11, 1385-1395. https://doi.org/10.1016/j.promfg.2017.07.268

Morgan, J.P. (2023). **What's next for the luxury market?** Disponível em: https://www.jpmorgan.com/insights/global-research/retail/luxury-market (Acesso em 15 de novembro de 2023).

Murmura, F., Bravi, L., Musso, F., & Mosciszko, A. (2021). **Lean Six Sigma for the improvement of company processes: The Schnell S.p.A. case study**. *The TQM Journal*, 33(7), 351-376. https://doi.org/10.1108/TQM-06-2021-0196

Nonthaleerak, P., & Hendry, L. (2008). **Exploring the six-sigma phenomenon using multiple case study evidence.** *International Journal of Operations & Production Management*, 28(3), 279-303. https://doi.org/10.1108/01443570810856198

Pereira, M.T., Bento, M.I., Ferreira, L.P., Sá, J.C., Silva, F.J.G., & Baptista, A. (2019). **Using Six Sigma to analyze customer satisfaction at the product design and development stage**. *Procedia Manufacturing*, 38, 1608-1614. https://doi.org/10.1016/j.promfg.2020.01.124

Prasad, S., Khanduja, D., & Sharma, S.K. (2018). **A study on implementation of lean manufacturing in Indian foundry industry by analysing lean waste issues**. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, 232(2), 371-378. https://doi.org/10.1177/0954405416640169

Proudlove, N., Moxham, C., & Boaden, R. (2008). **Lessons for Lean in healthcare from using Six Sigma in the NHS.** *Public Money & Management*, 28(1), 27–34. https://doi.org/10.1111/j.1467-9302.2008.00615.x

Rosa, C., Silva, F.J.G., & Ferreira, L.P. (2017). **Improving the quality and productivity of steel wire-rope assembly lines for the automotive industry**. *Procedia Manufacturing*, 11, 1035-1042. https://doi.org/10.1016/j.promfg.2017.07.214

Rong, K., Ding, H., Song, B., Gao, J., & Tang, J. (2021). **Data-driven process control for manufacturing spiral bevel and hypoid gears by using design for six sigma (DFSS) considering numerical loaded tooth contact analysis (NLTCA).** *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, 235(12), 1875-1891. https://doi.org/10.1177/09544054211023625

Silva, F.J.G., & Gouveia, R.M. (2020). **Cleaner Production – Toward a Better Future**. Cham, Suíça: Springer Nature Switzerland. ISBN: 978-3-030-23164-4.

Trubetskaya, A., Ryan, A., Powell, D.J., & Moore, C. (2024). **Utilising a hybrid DMAIC/TAM model to optimise annual maintenance shutdown performance in the dairy industry: A case study**. *International Journal of Lean Six Sigma*, 15(8), 70-92. https://doi.org/10.1108/IJLSS-05-2023-0083.