International Journal of Computer Information Systems and Industrial Management Applications
ISSN 2150-7988 Volume 18(22s) 2026 pp. 1675-1691
https://doi.org/10.70917/ijcisim-2026-5764
Article

Impact of Standardization and Lean Six Sigma Methodologies on Waste Reduction: Evidence from Goldsmith Workshops in Guerrero, Mexico

Julio César Flores Cabrera[1]*, Norma Rodríguez Bucio[1], Verónica Petra Hernández Pastrana[1], Pascual Felipe Perez Cabrera[1], Juan Carlos Kido Miranda[1], Agustín Acevedo Figueroa[1]

[1]National Technological Institute of Mexico / Technological Institute of Iguala, Iguala, Guerrero, Mexico
Email: jcesar.flores@iguala.tecnm.mx

Abstract: This study examines the impact of process standardization, administrative controls, and Lean Six Sigma methodologies on waste reduction in goldsmith workshops located in Guerrero, Mexico. Using an exploratory mixed-methods design, data were collected through structured interviews with managers and owners of 20 jewelry workshops in Taxco and Iguala. The analysis evaluated process documentation practices, administrative controls, critical production stages, and the implementation of continuous improvement methodologies in relation to reported material losses. Results indicate that workshops with documented procedures and structured management systems reported lower waste levels than those operating without formal controls. Acid treatment, sanding, and polishing were identified as the production stages most associated with material losses. Workshops implementing Manufacturing Excellence and Six Sigma achieved the lowest average waste rate (2.5%), compared with workshops using alternative methodologies or no formal methodology. The findings suggest that process standardization and Lean Six Sigma practices are associated with lower reported waste levels in artisanal jewelry workshops.
Keywords: Lean Six Sigma; Process Standardization; Waste Reduction; Administrative Controls; Jewelry Manufacturing; Artisanal Workshops; Operational Efficiency

1. Introduction

The jewelry industry occupies a significant position at the intersection of cultural heritage, artisanal craftsmanship, and economic development. Across various countries, jewelry production has emerged from traditional family-based activities into highly competitive industries that must fulfill modern demands for quality, competence, sustainability, and international competitiveness. Regardless of this transformation, most of the small and medium-sized jewelry enterprises rely on the inherited production practices, which are characterized by confined process documentation, informal management systems, and low levels of operational standardization (Alonso Aguilar et al., 2024; Rodríguez-Aldana & Reynoso, 2021). As these traditional practices significantly contribute to the individuality and artistic value of handcrafted jewelry, they might even increase the process variability, decrease the operational efficiency, and create significant material losses in production (Ortiz et al., 2024).

One of the most tenacious challenges in jewelry manufacturing refers to the management of production waste, commonly known as *merma*. Waste is actually a loss of raw material, which happens during manufacturing processes because of cutting, polishing, filing, melting, chemical treatments, errors in handling, or inefficiencies in process (Almeida et al., 2017; González et al., 2020). The literature distinguishes between the normal waste, expected under the standard production conditions, and the abnormal waste, which results from avoidable inefficiencies, insufficient controls, or poor process management(Almeida et al., 2017). In the industries that process high-value raw materials like gold and silver, even small percentages of waste can translate into considerable economic losses (Ortiz et al.,

Copyright: © 2026 by the authors

2025). Accordingly, waste reduction has been a strategic objective directly linked to productivity, profitability, and long-term business sustainability.

The importance of waste control is mainly evident in the valuable metals sector, as gold and silver are traded internationally as commodities categorized by high prices and market volatility. Their value is affected by economic conditions, geopolitical uncertainty, inflation expectations, and investment demand (Kostelić et al., 2023; Vigne et al., 2017). As jewelry manufacturers have less influence over raw material prices, operational efficiency has been one of the few controllable factors that are capable of protecting the profit margins (Vargas Soto & Ávila García, 2024). Excessive waste not only increases production costs but also reduces competitiveness in the domestic and international markets (Alshizawi & Ithawi, 2026). Hence, improvement in the process control and minimizing material losses are important to ensure the sustainability of jewelry enterprises, mainly small artisanal workshops which operate with limited resources (Al-Shizawi, 2026).

In Mexico, the state of Guerrero is one of the most important jewelry-producing regions in the country (Akil et al., 2024). The cities of Taxco and Iguala have attained national and international recognition historically for silver and gold craftsmanship, individually, which contributes significantly to regional employment, cultural identity, and economic activity(García & Clausen, 2020; Sánchez Rangel, 2019). Most of the workshops operate as family-owned businesses in which technical knowledge is transmitted across the generations. Though this model tends to preserve the valuable artisanal traditions, it even results in low levels of formal management, confined technological adoption, and inadequate process documentation (Alonso Aguilar et al., 2024). Moreover, extensive globalization has put local producers under intense international competition, mainly from countries like Italy, where standardized production systems as well as advanced manufacturing practices have strengthened productivity and export performance (De Marchi et al., 2014; Matricano & Vitagliano, 2018) As Mexican jewelry exports continue to expand, bringing improvement in the operational efficiency has turned out to be critical to maintain competitiveness in global markets(Guzmán et al., 2016).

Contemporary manufacturing literature specifies process standardization as a fundamental prerequisite for performance improvement and waste reduction. Process standardization includes the systematic documentation, measurement, and control of operational activities for ensuring the consistency and repeatability in production outcomes (Pablo David, 2019; Vivanco Vergara, 2017). Standardized procedures are helpful for facilitating the training, monitoring, quality assurance, and continuous improvement to establish clear operational guidelines and performance indicators (Akil et al., 2019). From a management viewpoint, effective control systems rely on the ability to measure and evaluate the process performance, making documentation a vital foundation for organizational improvement(Llanes-Font et al., 2014).

Among the most influential methodologies for operational excellence are Lean Manufacturing and Six Sigma. Lean Manufacturing emphasises eliminating the non-value-added activities and reducing the waste through the production process. While improving process flow, decreasing unnecessary activities, and optimizing resource utilization, Lean contributes towards higher productivity and enhanced product quality (Powell et al., 2017). Six Sigma tends to complement this approach while concentrating on reducing the process variability and defects by the statistical analysis and structured problem-solving techniques, mainly the DMAIC framework (Define, Measure, Analyze, Improve, and Control) (Moosa & Sajid, 2010). Many studies have demonstrated that Six Sigma implementation can create considerable savings, enhance quality performance, and improve operational efficiency in both large organizations and small and medium-sized enterprises (Antony, 2008; Cardona Zuluaga & Manzur Hasbun, 2015).

Integrating Lean Manufacturing and Six Sigma into the Lean Six Sigma framework has attained considerable attention in recent years because of its ability to concurrently address waste elimination as well as variability reduction (Bajgain et al., 2025). Research has proved that Lean Six Sigma improves operational performance, quality of product, environmental sustainability, and customer satisfaction across a broad range of industrial sectors (Caiado et al., 2018; da Silva et al., 2019). Recent studies have even demonstrated its contribution towards sustainable manufacturing and circular economy initiatives by the reductions in terms of material consumption and waste generation (Alanezi &

Franchetti, 2025; Huang et al., 2023; Porras et al., 2023; Ramírez et al., 2024). Regardless of these documented benefits, empirical evidence about the application of Lean Six Sigma in artisanal jewelry production is extremely limited (Praveen et al., 2025).

Existing research on the jewelry sector has mainly focused on the competitiveness, marketing strategies, production planning, and certification systems (Ferreira et al., 2021; Peralta Vera, 2024; Rodríguez-Aldana & Reynoso, 2021). Few studies have quantitatively assessed the waste generation in jewelry manufacturing, and even fewer have assessed the relationship between process standardization, administrative controls, and Lean Six Sigma implementation in the artisanal workshops (Balasubramanian et al., 2026). Furthermore, limited empirical evidence is available that identifies the particular production stages contributing most significantly to material losses in precious metal manufacturing (Ortiz et al., 2025). This particular gap is relevant as artisanal production is even perceived as incompatible with the standardized management systems, regardless of evidence that suggests that standardization can be applied successfully to operational processes while not compromising product creativity or craftsmanship(Gewehr & da Cruz, 2023).

This study pays heed to this research gap while investigating the effect of process standardization and Lean Six Sigma methodologies on the waste reduction in goldsmith workshops located in Guerrero, Mexico (Akil et al., 2023). With the use of empirical data gathered from workshops working in the major jewelry-producing cities of Taxco and Iguala, the research assesses the relationship between process documentation, administrative controls, continuous improvement practices, and waste levels (Akil et al., 2024). Much attention is given to identifying key production stages where intervention efforts can create the greatest reductions in terms of material losses.

The novelty of this study is in its provision of one of the prime quantitative assessments of waste management practices in the Mexican artisanal jewelry sector. It even contributes by integrating the process standardization, administrative controls, Lean Manufacturing, and Six Sigma into a unified analytical framework, particularly designed for precious metal production environments (Bajgain et al., 2022). In addition, the study identifies critical production processes that are associated with the highest waste levels and validates that methodologies traditionally applied in industrial settings can be adapted effectively to small, family-owned artisanal workshops (Bajgain, 2025). Thus, the main objective of this research is to assess the impact of process standardization and Lean Six Sigma methodologies on the waste reduction in goldsmith workshops in Guerrero, Mexico, and identify the critical processes and management practices contributing to improved operational performance, competitiveness, and sustainability (Parikh, 2026d).

2. Theoretical Framework

This study is theoretically based on the process management theory, administrative control theory, Lean Manufacturing philosophy, and Six Sigma quality management principles. Process management theory tends to argue that organizational performance can be improved by the systematic design, measurement, control, and improvement of operational activities improvement(Llanes-Font et al., 2014).From this viewpoint, production processes must be viewed as interconnected systems whose efficiency is reliant on standardization and continuous monitoring (Parikh, 2026b).

The concept of administrative control originated from classical management theory, particularly the work of Fayol (1916), who found control to be one of the major managerial functions(Fayol, 2016). Administrative controls let the organizations compare actual performance against the established standards and execute the corrective actions when deviations occur (Parikh, 2025c). In manufacturing environments, controls like production records, quality inspections, and operational audits contribute to the process stability and performance improvement (Hernández, 2020).

Lean Manufacturing gives an additional theoretical foundation while focusing on eliminating waste and maximizing value creation. Lean theory finds waste as any activity that consumes resources while not adding value to

the final product (Parikh, 2025b). Through continuous improvement and process optimization, organizations can decrease inefficiencies and enhance operational performance (Powell et al., 2017).

Six Sigma theory complements Lean while focusing on process variation and defect reduction. The DMAIC methodology helps promote evidence-based decision-making and systematic problem-solving for achieving higher levels of quality and consistency(Moosa & Sajid, 2010). Preceding studies have discussed that Six Sigma can create substantial operational improvements even in small and medium-sized enterprises (Antony, 2008; Parikh, 2026a).

Integrating Lean Manufacturing and Six Sigma forms the Lean Six Sigma framework, combining the waste elimination with variability reduction. Such an integrated approach has been identified as an effective strategy to enhance the operational excellence, sustainability, and competitiveness in the manufacturing organizations (Caiado et al., 2018; da Silva et al., 2019). This study uses all these theoretical perspectives for understanding and explaining the waste reduction in the artisanal goldsmith workshops (Parikh, 2024).

2.1 Conceptual framework

The conceptual framework of this study is based on the premise that waste generation in goldsmith workshops is affected by the level of process control, including the adoption of continuous improvement practices. In artisanal jewelry manufacturing, production activities like alloying, casting, soldering, filing, polishing, and acid treatment include direct manipulation of precious metals, which makes them highly susceptible to material losses. The framework suggests that waste reduction is not completely dependent on technical skills, but also on implementing structured management practices.

Process standardization establishes the first component of the framework. Standardized procedures give operational consistency, facilitate monitoring, and develop clear guidelines for workers. According to the documentation, workshops can classify deviations, measure performance, and execute the corrective actions.

Administrative controls are the second component and include production records, quality inspections, waste monitoring systems, and comparative analyses between planned and actual production outcomes. Such controls improve traceability while supporting informed decision-making. The third component includes Lean Manufacturing practices, which focus on the elimination of non-value-adding activities and reducing operational inefficiencies. Lean principles seek to minimize the waste that arises from excessive handling, needless movements, rework, and process delays. Complementing Lean, Six Sigma brings a data-driven approach towards decreasing the process variability and defects by systematic problem-solving and performance measurement. Integrating Lean Manufacturing and Six Sigma creates a comprehensive improvement system that is capable of simultaneously addressing waste generation and process inconsistency.

The framework considers that the combined implementation of process standardization, administrative controls, Lean Manufacturing, and Six Sigma practices positively affects the operational performance while reducing the material losses during production. Reduced waste levels contribute to enhanced productivity, lower production costs, higher profitability, and enhanced competitiveness. Accordingly, waste reduction works as an instant operational outcome, and improved organizational sustainability and market competitiveness tend to constitute the extensive strategic outcomes of the proposed framework.

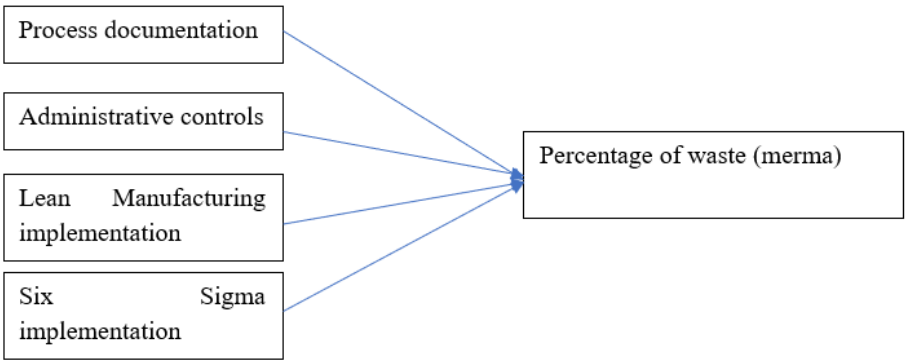


Figure 1. Conceptual Framework

2.2 Research Gap

Though Lean Manufacturing and Six Sigma have been studied extensively in industrial and large-scale manufacturing environments, empirical evidence about their application in artisanal jewelry production is limited. Existing studies mainly focus on the competitiveness, marketing strategies, certification systems, production planning, and business development in the jewelry sector (Ferreira et al., 2021; Peralta Vera, 2024; Rodríguez-Aldana & Reynoso, 2021). Accordingly, there is a lack of quantitative research that examines the determinants of waste generation and the effectiveness of structured management practices to reduce the material losses in precious metal workshops (Parikh, 2025a).

Moreover, preceding studies rarely explore the relationship between process standardization, administrative controls, and Lean Six Sigma implementation in the traditional artisanal production systems (Parikh, 2026c). The majority of accessible research has been conducted in industrial manufacturing contexts, which leaves uncertainty about the applicability of such methodologies in family-owned workshops that are characterized by informal management structures and craft-based production processes.

Another key gap is identifying specific production stages that are responsible for the highest levels of waste generation (Parikh, 2025d). Less evidence is available about which operational activities contribute most significantly to the material losses in goldsmith workshops and how targeted interventions can improve performance. Thus, this study addresses a key theoretical and practical gap by giving quantitative evidence from the Mexican jewelry sector and assessing the effectiveness of process standardization and Lean Six Sigma practices to reduce the waste and enhance competitiveness within the artisanal manufacturing environments.

3. Methods

3.1 Research Design

This study adopted an exploratory descriptive mixed-methods design. Quantitative data were obtained from closed-ended questionnaire items measuring workshop characteristics, administrative controls, production-process monitoring, methodology adoption, and reported waste percentages. Qualitative information was collected from open-ended responses regarding operational practices and perceived causes of material losses. The exploratory design was chosen as empirical research examining material waste (*merma*) management in the artisanal goldsmith workshops remains scarce, specifically within the Mexican jewelry sector. Exploratory studies are suitable when investigating under-researched phenomena and when the objective is to attain a deeper understanding of relationships among variables that have not been examined extensively in previous literature.

The study used a non-experimental design as the researchers did not manipulate any of the variables or introduce controlled interventions in the participating workshops. Rather, existing production practices, administrative controls, and waste levels were found and analyzed in their natural operational settings. The approach was considered suitable

as per the artisanal nature of the sector and the practical limitations linked with experimentally altering production systems in functioning workshops. Moreover, the research had a descriptive-correlational scope, which aimed to describe current waste management practices and examine the relationship between process standardization, administrative controls, Lean Manufacturing, Six Sigma implementation, and reported waste levels.

3.2 Study Setting

The study was done in the state of Guerrero, Mexico, mainly focusing on goldsmith workshops located in the cities of Iguala and Taxco. The cities were chosen as they represent the most significant jewelry production centers in the region. Taxco is recognized internationally for silver craftsmanship, and Iguala is famous for its gold jewelry production. Both of the locations have a long-standing artisanal tradition and contribute significantly to the regional economic activity.

The chosen setting gave a suitable environment to investigate the waste management practices, as the workshops process high-value raw materials like gold and silver, where even minor material losses can create substantial economic consequences. In addition, the predominance of family-owned businesses and traditional production methods provided an opportunity for examining the applicability of modern process improvement methodologies within artisanal manufacturing environments.

3.3 Participant Details

The target population comprises formally operating goldsmith workshops that are located within the state of Guerrero. Referring to the original study, a total population of 37 workshops was found. Workshop owners, managers, or individuals directly involved in production supervision served as the main respondents as they had detailed knowledge about the production processes, operational controls, waste levels, and management practices.

To ensure the reliability and relevance of the information gathered, workshops were needed to meet particular inclusion criteria. Eligible workshops had to demonstrate a minimum level of operational formality, use at least five workers, and maintain regular production activities. These criteria were made to ensure that participation in workshops had sufficiently structured production systems that were capable of providing meaningful information about waste generation and process management practices.

3.4 Sampling Method

A non-probabilistic purposive sampling strategy was used. The approach was justified due to the highly closed and traditional nature of the goldsmith sector, in which access to operational information is even restricted. Many workshops consider the production practices, material consumption, and waste levels to be sensitive business information, which makes the probability-based sampling difficult for implementation.

Depending on the population of 37 workshops, an initial sample size of 15 workshops was calculated with the use of a confidence level of 95%, a Z-value of 1.96, and a margin of error of 20%. Through direct engagement with workshop owners and managers, the effective sample was extended to 20 workshops. This higher level of participation improved the representativeness of the study and gave a wider perspective on production practices in the regional goldsmith sector.

3.5 Data Collection Tools

Data were collected with the use of a structured questionnaire administered by face-to-face interviews that were conducted at the participating workshops. The questionnaire was made considering the research objectives as well as the variables found in the literature about waste management, process control, and continuous improvement methodologies.

The instrument had closed-ended and open-ended questions, which were designed to collect qualitative and quantitative information. Mainly, the questionnaire gathered data about the type of metal processed, the existence of

documented production procedures, administrative control mechanisms, production phases subject to monitoring, critical operational processes, implementation of Lean Manufacturing and Six Sigma methodologies, reported waste percentages, and perceptions regarding the usefulness of the process controls.

Using a structured questionnaire ensured consistency across the interviews and facilitated the systematic collection of comparable information from the participating workshops. Face-to-face administration was chosen as it allowed clarifying the questions, higher response accuracy, and enhanced participation rates in a sector characterized by confined formal documentation.

3.6 Data Collection Procedure

Data collection was conducted by on-site visits to all participating workshops. Before interviews, workshop representatives were informed regarding the objectives of the study and invited to participate voluntarily. Once consent was attained, the structured questionnaire was directly administered to workshop owners, managers, or production supervisors.

The interviews were done in the operational environments of the participants, which enabled researchers to gain a contextual understanding of production activities and management practices. Responses were recorded and then organized for the qualitative categorization and quantitative analysis. The on-site approach even improved data reliability while allowing researchers to clarify the ambiguities and verify information directly with respondents.

3.7 Materials Used

The primary research material consisted of the structured questionnaire used in the interviews. Further materials included interview records, field notes, production documentation provided by participating workshops, along with the data registration sheets that are used for organizing responses.

The variables assessed in the study included the type of metal processed, process documentation, administrative controls, controlled production stages, critical procedures, implementation of Lean Manufacturing and Six Sigma methodologies, perceived benefits of controls, and final waste percentages. All the variables were chosen as they directly corresponded to the study objective to evaluate factors linked with waste reduction in the goldsmith production processes.

3.8 Data Analysis Method

Data analysis had both qualitative and quantitative techniques. Qualitative responses attained from open-ended questions were divided according to recurring themes and operational characteristics. This categorization helped in the identification of common practices and perceptions about waste management and process controls.

Quantitative analysis emphasised descriptive and correlational techniques. Frequency distributions were used for summarizing the workshop characteristics and management practices. Graphical correlation analyses were done to examine the relationships between waste percentages and key variables, which included process documentation, number of administrative controls, and execution of Lean Manufacturing and Six Sigma methodologies. In addition, linear trend projections were used for identifying the patterns and relationships among variables.

The combination of qualitative and quantitative analyses was appropriate as it gave both contextual understanding and empirical evidence about the factors that influence the waste generation in the artisanal goldsmith workshops.

3.9 Ethical Considerations

The study adhered to the essential ethical principles in the research process. Participation was voluntary, whereas informed consent was obtained from all the respondents before data collection. Participants were informed regarding the objectives of the study, the projected use of the information collected, and their right to withdraw from the research at any time.

For protecting confidentiality, the identities of participating workshops and respondents were not disclosed in the publication or research output. Data were analyzed and reported in aggregate form to prevent the identification of individual businesses. Moreover, all information collected was exclusively used for academic and research purposes. These measures were mainly important, given the sensitive nature of production and financial information in the goldsmith sector, and contributed to establishing trust between the researchers and participants.

4. Results

4.1 Characteristics of Surveyed Workshops

Overall, 20 jewelry workshops had taken part in the study. The distribution of workshops as per the primary metal processed specifies a predominance of silver-working establishments (50%), followed by gold (30%) and steel (20%). This distribution shows the production structure of the local jewelry sector and signifies the relevance of silver manufacturing activities in the sample.

Table 1. Characteristics of Surveyed Workshops (n = 20)

Variable	Category	Frequency	Percentage
Metal Processed	Gold	6	30.0
	Silver	10	50.0
	Steel	4	20.0
Process Documentation	Yes	18	90.0
	No	2	10.0

Table 1 shows that most workshops had reported maintaining documented production procedures. This suggests widespread adoption of the administrative controls. Nonetheless, a minority of establishments still operate without formal documentation, significantly increasing the operational variability and material losses.

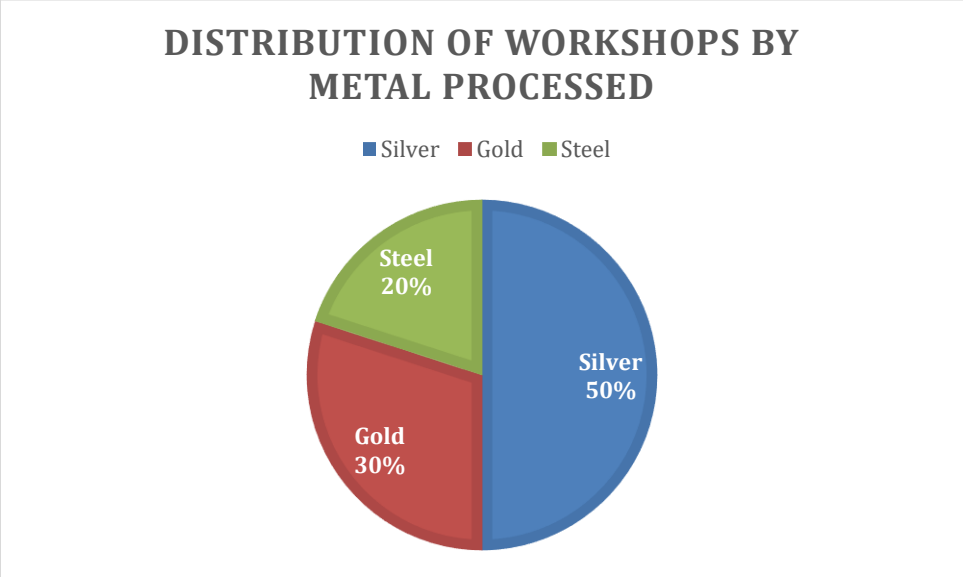


Figure 2. Distribution of Workshops by Metal Processed

Figure 2 represents silver-processing workshops, which constitute the largest segment of the sample, representing half of all surveyed establishments. The majority of silver production may affect the waste profile of the sector because of differences in the material handling requirements and production complexity.

4.2 Adoption of Administrative Controls

Administrative controls are important to monitor the production activities and minimize operational inefficiencies. The results show that 90% of workshops maintain documented production processes, but only 10% operate without formal documentation.

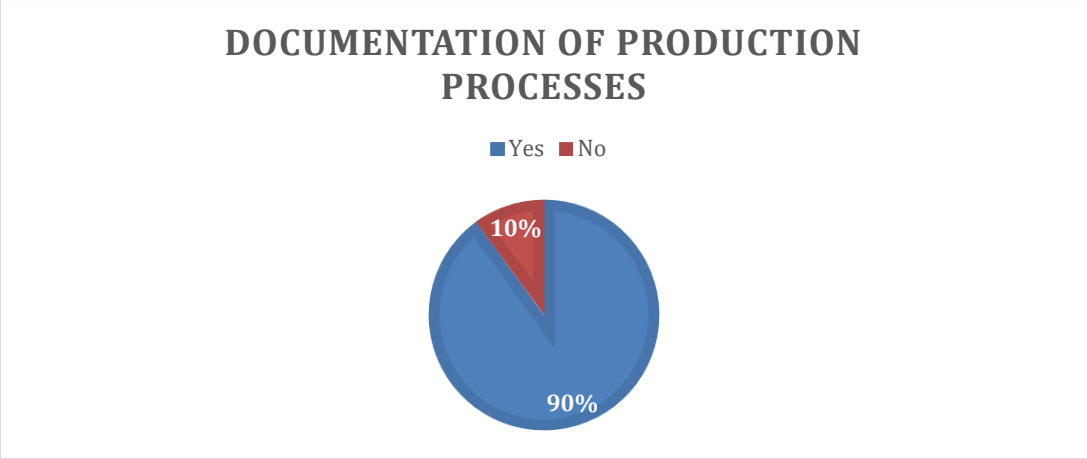


Figure 3. Documentation of Production Processes

Figure 3 shows that 18 of the 20 surveyed workshops reported having documented production processes.. Though the presence of undocumented workshops suggests opportunities for improvement in standardization practices.

Table 2. Administrative control for waste registration

Control type	n	%
Specific format	10	50
Data without format	10	50
Logbook	4	20
None	0	0

Regarding waste registration practices, Table 2 shows that half of the workshops reported using specific formats, while the remaining workshops recorded waste information without a standardized format. Four workshops maintained operational logs.

4.3 Critical Production Processes Associated with Material Losses

The surveyed workshops found many production phases to be critical sources of waste generation. Among these, acid treatment, sanding, polishing, rolling, and finishing operations were most frequently cited.

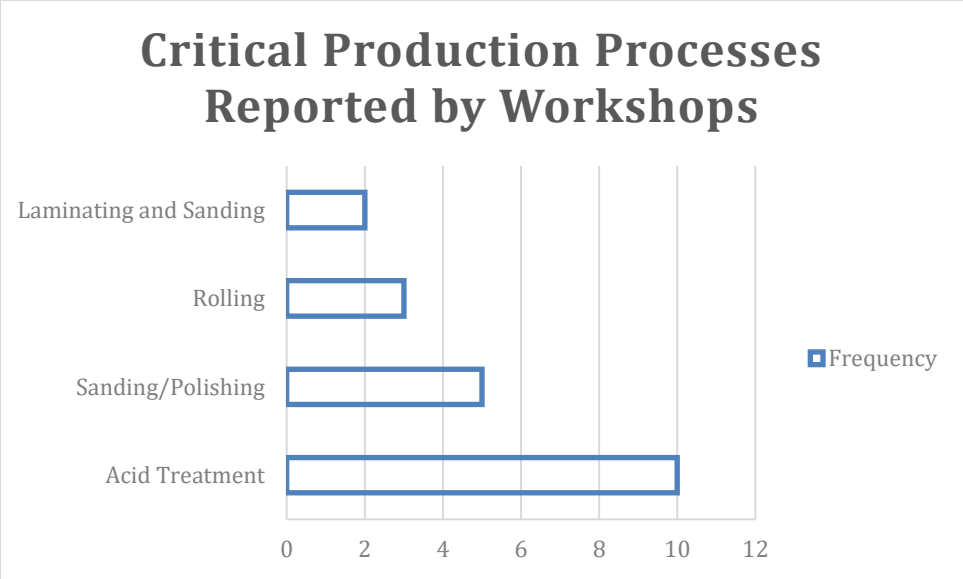


Figure 4. Critical Production Processes Reported by Workshops

Figure 4 shows that acid treatment emerged as the most critical operation, accounting for half of all responses. The finding suggests that the chemical treatment stages show significant opportunities for the waste-reduction interventions and process optimization.

4.4 Relationship Between Management Methodologies and Waste Generation

Three categories of management methodologies were found among participating workshops: Manufacturing Excellence (ME), which was combined with Six Sigma, other internal methodologies, and the absence of formal management methodologies.

Table 3. Waste Percentage According to the Methodology Implemented

Methodology	Workshops (n)	Average Waste (%)
ME + Six Sigma	4	2.5
Other Methodologies	4	12.75
None	12	15.8

Table 3 shows that workshops that implement ME + Six Sigma have reported substantially lower waste levels in comparison to those using alternative approaches or no methodology at all. These findings recommend that structured continuous-improvement frameworks contribute significantly to waste minimization.

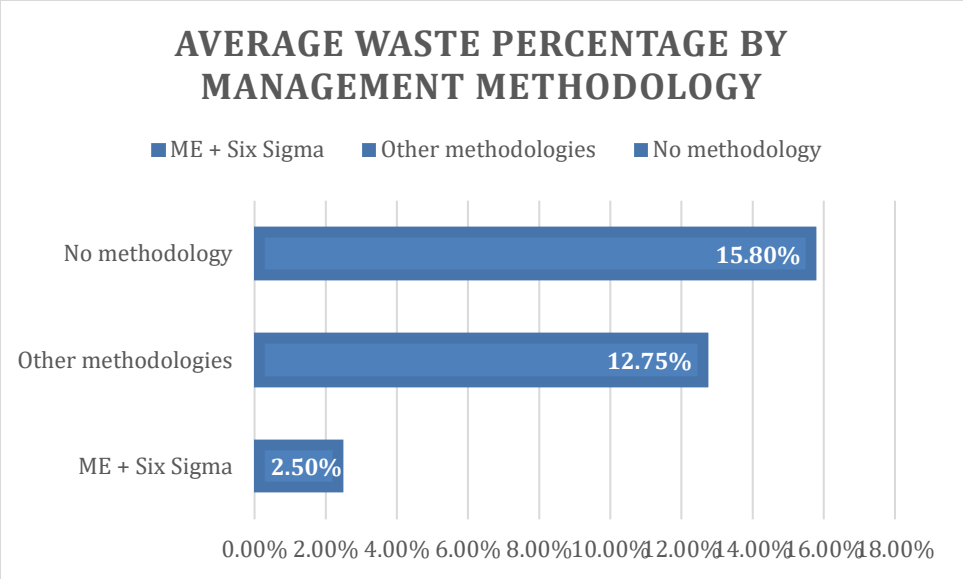


Figure 5. Average Waste Percentage by Management Methodology

Average reported waste percentages differed among workshops according to the methodology category (**Figure 5**). Workshops using advanced quality-management systems attained considerably lower waste rates, which reinforced the effectiveness of systematic process improvement practices.

4.5 Influence of Process Documentation on Waste Reduction

For evaluating the effectiveness of administrative controls, waste percentages were compared between workshops with documented and undocumented production processes.

Table 4. Waste Percentage by Documentation Status

Documentation	Workshops (n)	Average Waste (%)
Documented	18	12.1
Not Documented	2	20.0

Table 4 shows that undocumented workshops had reported the highest waste levels observed in the study. The results prove that lower reported waste percentages were observed among workshops with documented processes and lower material losses.

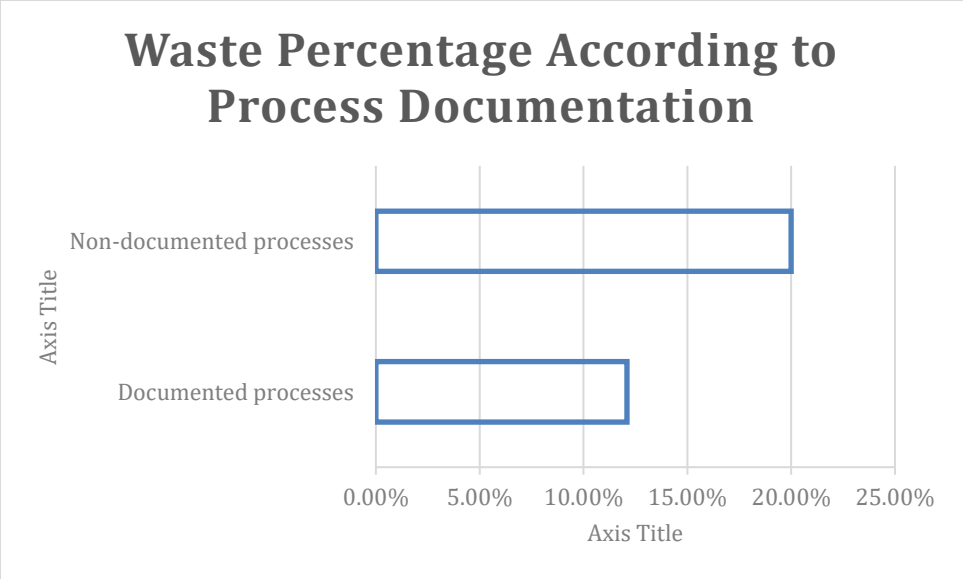


Figure 6. Waste Percentage According to Process Documentation

The findings shared in **Figure 6** reveal a considerable difference in waste generation between documented and undocumented workshops. Process standardization appears to support better control of production activities as well as more efficient use of raw materials.

5. Discussion

The findings of this study provide empirical evidence that administrative controls, process standardization, and Lean–Six Sigma methodologies play a significant role in reducing material losses in jewelry workshops. Though 90% of the surveyed workshops reported having documented production procedures, the results specify that documentation alone does not guarantee optimal performance. Workshops having documented processes continued to report waste levels that range from 2% to 20%, which suggests that standardization must be viewed as a basic requirement instead of a complete solution. This observation is consistent with the principles of internal control that were proposed by (Barquero, 2013) and (Hernández, 2020).emphasizing that documentation is effective only when it is accompanied by monitoring mechanisms as well as corrective actions. Similarly, (Vergara Nieto et al., 2025) argues that the procedural manuals work as instruments for organizational control; their effectiveness is dependent on consistent implementation and operational discipline (Quraishi et al., 2025).

The analysis even revealed that waste generation is concentrated in particular production stages, mainly sanding, polishing, and acid treatment. Workshops that focused their control efforts on such critical activities generally reported lower material losses than those that depended on generalized administrative oversight (Quraishi et al., 2026). This finding supports the process-management perspective shared by (Llanes-Font et al., 2014) arguing that organizational performance is enhanced when management efforts are directed toward value-generating and high-risk activities. Alike conclusions were reached by (Mendoza-Arvizo & Thelma Solís-Rodríguez, 2022) demonstrating that process optimization in small manufacturing firms is quite effective when interventions target bottlenecks and critical operations instead of attempting broad, non-prioritized improvements (Alqasrawi et al., 2026). Provided the high economic value of precious metals, even small inefficiencies in such stages can have significant financial consequences, which reinforced observations by (Távara Maza, 2019)and (González et al., 2020) about the effect of production losses on the manufacturing costs and profitability.

The most important finding significantly concerns the relationship between management methodologies and waste reduction. Workshops that implement Manufacturing Excellence and Six Sigma attained an average waste level of 2.5%, considerably lower than the values observed among workshops with the use of alternative methodologies or

no formal methodology. This result ensures the growing body of evidence supporting Lean–Six Sigma as an effective framework for operational improvement in manufacturing environments. Six Sigma can be implemented successfully in small and medium-sized enterprises regardless of resource limitations, and the present findings give further support for this proposition within the context of artisanal jewelry production(Antony, 2008). Similar improvements are reported in metalworking and fabrication industries, in which Lean–Six Sigma interventions decreased process variability, setup times, and operational waste (Celis-Gracia et al., 2024; Medina, 2023).

The effectiveness of Lean–Six Sigma found in this study may be explained by its structured and data-driven approach to problem solving. Referring to (Tlapa et al., 2016) the successful implementation of Six Sigma is dependent on the integration of measurement systems, managerial commitment, and continuous improvement practices. Workshops that apply these principles are better positioned for identifying sources of variability and removing activities that do not add value. Moreover, (da Silva et al., 2019) focus on how Lean–Six Sigma improves organizational competitiveness by combining waste elimination with process stabilization, a mechanism that seems particularly relevant in jewelry production, where raw materials are expensive, and losses affect profitability directly.

The findings even contribute to the emerging literature relating to Lean–Six Sigma with sustainability. Recent studies discuss that a reduction in operational waste simultaneously enhances the economic and environmental performance(Alanezi & Franchetti, 2025; Huang et al., 2023). While minimizing material losses, jewelry workshops not only reduce production costs but also reduce the resource consumption and environmental effects associated with the precious-metal extraction and processing. These conclusions align with the ones shared by (Caiado et al., 2018; Porras et al., 2023; Powell et al., 2017; Ramírez et al., 2024) who found that Lean–Six Sigma initiatives often generate sustainability benefits by more efficient resource utilization. Integrating quality management, environmental responsibility, and operational excellence is highly recognized as a critical factor for long-term competitiveness in the manufacturing sectors(Boumsisse et al., 2024).

From an industry viewpoint, the results challenge the assumption that artisanal production and process standardization are mismatched. Jewelry manufacturing is traditionally associated with craftsmanship, customization, and artistic expression (Alonso Aguilar et al., 2024; Salcedo Restrepo, 1989). Though the evidence suggests that the standardization of intermediate production stages can coexist with the artisanal value creation. This finding is relatable to (Gewehr & da Cruz, 2023)who observed that artisanal sectors can preserve the product uniqueness while implementing standardized operational procedures. Same modernization efforts have been reported in the jewelry industries facing international competition, mainly in Italy, where process improvements and technological integration have contributed to the enhanced competitiveness (De Marchi et al., 2014; Matricano & Vitagliano, 2018).

Thus, the results indicate that the most effective pathway to reduce the material losses follows a progressive sequence. Workshops must first establish documented procedures and operational standards, then execute focused controls on the critical processes, and finally integrate Lean–Six Sigma methodologies into organizational culture. This progression shows the evolution from basic administrative control toward a comprehensive system of continuous improvement. The findings thus support the argument that the sustainable productivity gains in jewelry manufacturing are attained not by the isolated interventions but by the systematic integration of standardization, targeted process control, and data-driven improvement methodologies.

6. Conclusion

This study assessed the effect of administrative controls, process standardization, and quality-management methodologies on the material losses in jewelry workshops found in Guerrero, Mexico. The findings confirm the proposed hypothesis that standardization and the adoption of Lean–Six Sigma methodologies significantly contribute to reducing the material losses within jewelry manufacturing operations.

The results show that documentary standardization is a key prerequisite for process control, but is insufficient on its own for achieving the substantial performance improvements. The greatest reductions in the waste were

observed among workshops that combined documented procedures with focused monitoring of critical processes and the execution of structured continuous-improvement methodologies.

Among all production stages, sanding, polishing, and acid treatment are found to be the most critical processes associated with the material losses. Consequently, these activities show priority targets for operational improvement initiatives. Workshops executing Manufacturing Excellence and Six Sigma attained the lowest observed waste levels, which indicate the effectiveness of systematic problem-solving and process-optimization approaches in artisanal manufacturing environments.

The study even suggests that the most effective adoption pathway follows a progressive sequence: documentation of procedures, implementation of focused operational controls, and eventual integration of formal methodologies into organizational culture. This phased approach facilitates gradual capability development and minimizes resistance to organizational change.

From a theoretical perspective, the study contributes empirical evidence about the feasibility and effectiveness of Lean–Six Sigma methodologies in a traditional Mexican artisanal sector. The findings demonstrate that the quality-management principles commonly linked with large industrial organizations can even generate substantial benefits in the small-scale jewelry manufacturing environments.

6.1 Recommendations

The findings recommend that jewelry workshops must adopt a progressive improvement strategy centered on process standardization, targeted controls, and Lean–Six Sigma implementation. Primarily, workshops must establish electronic process logbooks and standardized operating procedures for improving documentation, traceability, and operational consistency. Effective documentation forms the basis for internal control and facilitates performance monitoring and decision-making(Barquero, 2013; Vergara Nieto et al., 2025).

Improvement efforts must prioritize critical production stages, mainly sanding, polishing, and acid treatment, which were found as the primary sources of material losses. Concentrating monitoring and corrective actions on such processes is likely to yield higher reductions in waste than applying generalized controls across all operations (Celis-Gracia et al., 2024; Mendoza-Arvizo & Thelma Solís-Rodríguez, 2022). Workshops must even establish Key Performance Indicators (KPIs) for monitoring the material loss by metal type and production stage.

For achieving the sustained improvements, managers and operators must receive training in Lean–Six Sigma principles, which include the DMAIC methodology and the identification of the seven Lean wastes. Preceding studies have demonstrated that such methodologies can significantly enhance the productivity, quality, and operational performance in small and medium-sized enterprises (Antony, 2008; da Silva et al., 2019; Tlapa et al., 2016). Lastly, industry associations and public institutions must promote specialized training and technical-support programs for jewelry-related MSMEs. These initiatives could improve competitiveness and reduce material consumption and support sustainable manufacturing practices, consistent with the recent evidence linking Lean–Six Sigma implementation to both economic and environmental benefits (Alanezi & Franchetti, 2025; Huang et al., 2023).

6.2 Future Research Directions

Future studies must examine the long-term effects of Lean–Six Sigma implementation by longitudinal analyses of jewelry workshops undergoing organizational transformation. Comparative studies including other jewelry-producing regions, such as Oaxaca, Jalisco, and Mexico City, would give valuable insights regarding regional differences in management practices and operational performance.

Further research should even investigate the integration of Industry 4.0 technologies, which include Internet of Things (IoT) devices, computer vision systems, and digital process-monitoring platforms, into critical production stages. Lastly, future investigations must quantify the financial impact of production controls and quality-management systems on profitability, competitiveness, and business sustainability within the jewelry sector.

Author Note

This article is based on the doctoral thesis entitled Administrative Controls to Reduce Waste in Production Processes in Goldsmith Workshops, submitted by Flores (2022) to Universidad IEXPRO.

REFERENCES

1. Alanezi, W., & Franchetti, M. (2025). Integrating Lean Six Sigma with Sustainable Manufacturing: A Framework for Optimized Efficiency and Environmental Performance. *Journal of Manufacturing Science and Engineering*, *147*(12), 121002.
2. Almeida, R. P., Romanzini, F., Amorin, A. L. W., Werner, L., & Neto, F. J. K. (2017). Controle do desempenho operacional na indústria plástica: uma abordagem estruturada para a avaliação de custos e planejamento da capacidade. *Revista Produção Online*, *17*(3), 931-955.
3. Alonso Aguilar, F. D., González Alvarado, T. E., & Cabanelas Lorenzo, P. (2024). Artisanal Businesses: Historical and Economic Context. *Mercados y negocios*, *25*(52), 53-76.
4. Antony, J. (2008). Can Six Sigma be effectively implemented in SMEs? *International Journal of Productivity and Performance Management*, *57*(5), 420-423.
5. Barquero, M. (2013). Manual práctico de control interno. *Barcelona: Profit*.
6. Boumsisse, I., Benhadou, M., & Haddout, A. (2024). Exploring the potential synergies between industry 5.0 and green lean six sigma for sustainable performance: A new dimension of operational excellence. *Evolutionary Studies in Imaginative Culture*, *8*, 1242-1259.
7. Caiado, R., Nascimento, D., Quelhas, O., Tortorella, G., & Rangel, L. (2018). Towards sustainability through green, lean and six sigma integration at service industry: review and framework. *Technological and Economic Development of Economy*, *24*(4), 1659-1678.
8. Cardona Zuluaga, E., & Manzur Hasbun, R. (2015). Aplicación de la metodología seis sigma para la disminución del indicador de la merma de envase retornable en la planta de Coca-Cola FEMSA nodo Medellín.
9. Celis-Gracia, O., García-Alcaraz, J. L., Estrada-Orantes, F. J., Avelar-Sosa, L., Alba-Baena, N. G., & Hermosillo-Villalobos, F. (2024). Reduction of Setup Times in a Metal Fabrication Company Using a Lean-Sigma Approach. *Enfoque UTE*, *15*(3), 41-48.
10. da Silva, I. B., Godinho Filho, M., Agostinho, O. L., & Junior, O. F. L. (2019). A new Lean Six Sigma framework for improving competitiveness. *Acta Scientiarum. Technology*, *41*, e37327.
11. De Marchi, V., Lee, J., & Gereffi, G. (2014). Globalization, recession and the internationalization of industrial districts: experiences from the Italian gold jewellery industry. *European Planning Studies*, *22*(4), 866-884.
12. Fayol, H. (2016). *General and industrial management*. Ravenio Books.
13. Ferreira, F. G., de Oliveira Gomes, L., Grangeiro, A. F. B., Cintra, T. R., de Mello, J. L. M., de Moraes Magalhães, P. R., & da Silva Cunha, C. (2021). Prevalência de depressão e fatores associados em idosos atendidos na Atenção Primária à Saúde em região metropolitana do Distrito Federal. *Scientia Medica*, *31*(1), e38237-e38237.
14. García, M. A. V., & Clausen, H. B. (2020). Los norteamericanos que reinventaron a los pueblos de México: Los emprendedores extranjeros en la redefinición de la cultura y el turismo. *Latin American Research Review*, *55*(1), 49-63.
15. Gewehr, B., & da Cruz, F. T. (2023). Calidad de los alimentos artesanales: paralelismos entre los quesos y cervezas artesanales brasileñas. *Revista agroalimentaria*, *29*(57), 147-166.
16. González, V. V., Barrios, E. H., & Hernández, E. E. (2020). Contabilización de los residuos sólidos generados en la fabricación de muebles de madera: Perspectiva teórica. *Dictamen Libre*(26), 183-191.
17. Guzmán, J. N. C., Vazquez, G., & Elizondo, F. J. B. (2016). Ventas al cliente final de la PYME comercial de la industria joyera en Guadalajara: Calidad en el servicio y Neuromarketing. *Mercados y Negocios: Revista de Investigación yy Análisis*(33), 59-80.
18. Hernández, M. (2020). La importancia del control en la administración. *Universidad Intercontinental*.
19. Huang, J., Irfan, M., Fatima, S. S., & Shahid, R. M. (2023). The role of lean six sigma in driving sustainable manufacturing practices: an analysis of the relationship between lean six sigma principles, data-driven decision making, and environmental performance. *Frontiers in Environmental Science*, *11*, 1184488.
20. Kostelić, K., BOŽAC, M. G., & Etinger, D. (2023). EXPLORATORY PATH ANALYSIS OF LIFE-CHOICE STRATEGIC DECISION-MAKING: THE CASE OF TERTIARY EDUCATION ENROLLMENT. *Ad alta: journal of interdisciplinary research*, *13*(2).
21. Llanes-Font, M., Isaac-Godínez, C. L., Moreno-Pino, M., & García-Vidal, G. (2014). De la gestión por procesos a la gestión integrada por procesos. *Ingeniería industrial*, *35*(3), 255-264.
22. Matricano, D., & Vitagliano, G. (2018). International marketing strategies in the jewellery industry: are they standardised, adapted or both? *International Journal of Marketing Studies*, *10*(1), 1-10.
23. Medina, C. A. I. (2023). Lean Six Sigma y mejora de la productividad en el servicio de reparación de equipos de minería en una empresa metalmecánica. *Industrial Data*, *26*(2), 239-265.
24. Mendoza-Arvizo, U., & Thelma Solís-Rodríguez, F. (2022). Quality, knowledge, and innovation of manufacturing processes in Ciudad Juárez, Mexico. *Retos, Revista de Ciencias Administrativas y Económicas*, *12*(23).

25. Moosa, K., & Sajid, A. (2010). Critical analysis of Six Sigma implementation. *Total Quality Management*, *21*(7), 745-759.
26. Pablo David, M. Y. (2019). *Estandarización de los procesos productivos en la empresa Lincoln* Universidad Nacional de Chimborazo 2019].
27. Peralta Vera, B. R. (2024). Propuesta de mejora para la planificación y control de la producción de una empresa que fabrica cadenas de oro y plata.
28. Porras, J. E. O., Erquínigo, A. M. B., Chávez, T. C. C., Palma, L. M. H., Torres, R. K. M., & Gomez, O. R. T. (2023). Green Lean Six Sigma model for waste reduction of raw material in a nectar manufacturing company of Lima, Peru. *Journal of Industrial Engineering and Management*, *16*(2), 169-185.
29. Powell, D., Lundeby, S., Chabada, L., & Dreyer, H. (2017). Lean Six Sigma and environmental sustainability: the case of a Norwegian dairy producer. *International journal of lean six sigma*, *8*(1), 53-64.
30. Ramírez, I. G., Reyes, J. M. C., Zárate, I. M., García, R. H., & Pérez, J. E. C. G. (2024). Hacia una Economía Circular: Una Revisión Sistémica de la Implementación de Green Lean Six Sigma en la Industria Manufacturera. *Ciencia Latina: Revista Multidisciplinar*, *8*(6), 3799-3816.
31. Rodríguez-Aldana, M. L., & Reynoso, C. F. (2021). Factores críticos de éxito del sector joyero de la Zona Metropolitana de Guadalajara: un análisis comparativo entre la industria y la literatura. *Revista Academia & Negocios*, *7*(2), 175-192.
32. Salcedo Restrepo, M. T. (1989). Artesanos momposinos y el carácter de los objetos de oro que elaboran: informe.
33. Sánchez Rangel, O. (2019). Génesis de una ciudad turística mexicana al comienzo del siglo XX: el antiguo centro minero de Guanajuato.
34. Távara Maza, S. I. (2019). Influencia de la merma en la determinación del costo de producción de una empresa industrial, Lima 2018.
35. Tlapa, D., Limon, J., García-Alcaraz, J. L., Baez, Y., & Sánchez, C. (2016). Six Sigma enablers in Mexican manufacturing companies: a proposed model. *Industrial Management & Data Systems*, *116*(5), 926-959.
36. Vergara Nieto, Á. A., Díaz, A. H., Hernández Millán, M., & Sagredo, D. (2025). Molecular Features, Effective Sources, and Physiological Effects of Omega-3 Unsaturated Fatty Acids on Cardiovascular, Neurological, and Muscular Health, and Clinical Relevance for Several Conditions: A Narrative Review. *Nutrition Reviews*, nuaf201.
37. Vigne, S. A., Lucey, B. M., O'Connor, F. A., & Yarovaya, L. (2017). The financial economics of white precious metals—A survey. *International Review of Financial Analysis*, *52*, 292-308.
38. Vivanco Vergara, M. E. (2017). Los manuales de procedimientos como herramientas de control interno de una organización. *Revista Universidad y sociedad*, *9*(3), 247-252.
39. Ortiz, S. Y. C., Vázquez, J. T., Bello, E. A., Estrada, U. L., & Erdosay, J. S. (2024). La Soya: Tesoro versátil, proteico y saludable importante en la dieta mexicana. Dialnet. https://dialnet.unirioja.es/servlet/articulo?codigo=9787138
40. Ortiz, S. Y. C., Cabrera, J. C. F., Castillo, M. Á. A., Pichardo, C. D. C., & Castillo, A. Á. A. (2025). Optimización del sector agrícola mediante el análisis de datos para una gestión eficiente de los recursos naturales: Una perspectiva para México. Dialnet. https://dialnet.unirioja.es/servlet/articulo?codigo=10104282
41. Vargas Soto, J. E., & Ávila García, J. F. (2024). Emprendedurismo e ingeniería [Entrepreneurship and engineering]. Asociación Mexicana de Mecatrónica A.C.
42. Alshizawi, M. S. A., & Ithawi, M. a. M. A. (2026). Negotiating Samāʿ and Qiyās: Epistemological Foundations of Grammar in Al-Suyūṭī's Hamʿ Al-Hawāmiʿ. GEMA Online Journal of Language Studies, 26(3), 708–723. https://doi.org/10.17576/gema-2026-2603-13
43. Al-Shizawi, M. S. (2026, August 27). Quantifying Cultural Fairness in Multilingual AI: A Cross-Lingual Evaluation of Representational Bias in Digital Humanities Corpora. https://www.jidmis.org/index.php/jidmis/article/view/2560
44. Akil, M., Martucci, L., & Hoepman, J.-H. (2023). Non-interactive privacy-preserving Sybil-free authentication scheme in VANETs. In Proceedings of the Symposium on Vehicle Security and Privacy (VehicleSec) 2023 (pp. 27–35). Internet Society. https://doi.org/10.14722/vehiclesec.2023.23007
45. Akil, M., Martucci, L., & Hoepman, J. (2024). A secure and privacy-preserving authentication scheme with a zero-trust approach to vehicle renting in VANETs. In Proceedings of the 21st International Conference on Security and Cryptography (SECRYPT 2024) (Vol. 1, pp. 114–127). SciTePress. https://doi.org/10.5220/0012759600003767
46. Akil, M., Naskar, S., Martucci, L. A., & Hoepman, J. (2024). A Privacy-Preserving approach to vehicle renting and driver accountability in VANETs. IFIP Advances in Information and Communication Technology, 192–210. https://doi.org/10.1007/978-3-031-57978-3_13
47. Akil, M., Mancini, L., V., & Venturi, D. (2019). Multi-covert channel attack in the cloud. DIVA. https://kau.diva-portal.org/smash/record.jsf?faces-redirect=true&aq2=%5B%5B%5D%5D&af=%5B%5D&searchType=SIMPLE&sortOrder2=title_sort_asc&language=sv&pid=diva2%3A1369702&aq=%5B%5B%5D%5D&sf=all&aqe=%5B%5D&sortOrder=author_sort_asc&onlyFullText=false&noOfRows=50&dswid=-2896
48. Bajgain, A., Jana, S. P., Chatterjee, S., Samokhvalov, A., Parker, T., Demaree, J. D., Asthana, A., Shock, C., & Budhani, R. C. (2025). Selenization of V2O5/WO3 bilayers for tuned optoelectronic response of WSe2 films. Applied Physics Letters, 127(8). https://doi.org/10.1063/5.0282009
49. Bajgain, A., Neupane, B. D., Sarraf, D., Karmacharya, J., Ranjitkar, S., Shrestha, R., & Gyawali, R. (2022). Quality evaluation of Apis laboriosa and Apis mellifera honey collected from Bagmati Province, Nepal. Nepal Journal of Biotechnology, 10(1), 32–39.

50. Bajgain, A. (2025). Novel growth strategy for vanadium-doped WSe_2 films with tunable optoelectronic properties (Master's thesis, Morgan State University).
51. Parikh, P. B. (2026). Implementing digital inspection protocols for enhanced quality control management in high-rise construction. Power System Protection and Control, 54(3), 147–163.
52. Parikh, P. B. (2026). Evaluating the feasibility and efficiency of 3D-printed concrete technology in sustainable modular construction. Power System Protection and Control, 54(1), 887–900.
53. Parikh, P. B. (2025). Optimizing the structural and durability performance of concrete using recycled aggregates and supplementary cementitious materials. Power System Protection and Control, 53(4), 564–576.
54. Parikh, P. B. (2025). Frameworks for mitigating supply chain disruptions and material price volatility in sustainable building construction. Power System Protection and Control, 53(2), 410–426.
55. Parikh, P. B. (2026). Advancing America's infrastructure: The role of artificial intelligence in construction management. Geh Press. https://books.google.com/books?id=Jt3uEQAAQBAJ
56. Parikh, P. B. (2024). Implementing digital inspection protocols: A university-level reference on intelligent, data-driven inspection systems. Geh Press.
57. Parikh, P. B. (2025). 3D-printed concrete technology in sustainable modular construction: Principles, materials, structural performance, digital fabrication, and sustainability assessment. Geh Press. https://books.google.com/books?id=zWH9EQAAQBAJ
58. Parikh, P. B. (2026). Frameworks for mitigating supply chain disruptions and material price volatility in sustainable building construction. Geh Press. https://books.google.com/books?id=U2H9EQAAQBAJ
59. Parikh, P. B. (2025). Optimizing the structural and durability performance of concrete using recycled aggregates and supplementary cementitious materials. Geh Press. https://books.google.com/books?id=G2L9EQAAQBAJ
60. Quraishi, M. A., Salam, A., Agarwal, A., & Ñaca, P. Q. (2025). Cyber-Physical Co-Design Reliability Framework for ASIL-D Automotive Sensor ECUs with Integrated Hardware–Software Fault Tolerance and Security. Journal of Information Systems Engineering & Management, 10, 671-683.
61. Praveen, N. B., Quraishi, M. A., & Mudliar, S. S. (2025, October 7). Securing Low-Power Edge AI: A vulnerability analysis and cybersecurity framework for Resource-Constrained Devices. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5588331
62. Balasubramanian, P. N., Quraishi, M. A., Waggeh, A., & Shahid, M. A. (2026). Exploiting and Securing Machine Learning: A Cybersecurity perspective on Adversarial vulnerabilities and Countermeasures. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.5799502
63. Quraishi, M. A., Sunkara, G., Majeed, R., Bolaños Rodríguez, H. A., Alqasrawi, Y., Ferdouse, M. A. B., & Oropesa, C. M. (2026). Machine learning for optimized microgrid management: Advances, applications, operational efficiency, system resilience, cybersecurity, and future technologies. MSW Management: Multidisciplinary, Scientific Work and Management Journal, 36(2), 2501–2504.
64. Alqasrawi, Y., Radhakrishnan, V., Pham, T. N.-P., Quraishi, M. A., Subramananian, P., & Sheikh, A. (2026). Integrating artificial intelligence and machine learning with chemical bonding descriptors: Applications in molecular property prediction, reactivity analysis, and materials design. Scientific Culture, 12(4), 5138–5149.
65. Ortiz, S. Y. C., Bello, E. A., Cabrera, J. C. F., Quiroz, A. C., & Vázquez, J. T. (2025). Uso de IoT para Monitoreo de la Eficiencia Hídrica en Genotipos de Soya. Estudios Y Perspectivas Revista Científica Y Académica, 5(1), 2687–2703. https://doi.org/10.61384/r.c.a..v5i1.1014