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CASE STUDY

Challenges in data collection for enhancing productivity in Brazilian industrial processes

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ABSTRACT

Goal: To understand the underlying reasons for low productivity in medium-sized metalworking companies and to evaluate the effectiveness of the productivity improvement techniques that have been implemented.

Design / Methodology / Approach: The research adopted an exploratory design, employing both qualitative and quantitative methods. This included content analysis and semi-structured interviews with company managers. Twelve medium-sized enterprises in the metalworking sector were selected, and data were collected from thesis projects conducted between 2017 and 2019. The interviews were conducted via phone or video conferencing with managers in 2023.

Results: The findings indicate that productivity improvement techniques, including Lean Six Sigma, PDCA, and Value Stream Mapping, were partially implemented in some companies but were abandoned in others due to the pandemic and internal cultural barriers. Only a minority of companies succeeded in sustaining their productivity programs.

Limitations of the Investigation: The primary limitations include the reluctance of companies to provide detailed data, challenges in maintaining improvement programs due to the pandemic, and restricted access to internal information owing to industrial confidentiality.

Practical Implications: This study underscores the necessity for enhanced methodological strategies to foster company collaboration and robust data collection in productivity research, offering insights into the challenges faced by medium-sized companies in Brazil.

Originality / Value: This research provides a unique comparison of productivity challenges encountered by medium-sized Brazilian companies in the metalworking sector, particularly in the context of the COVID-19 pandemic, thus contributing to the discourse on industrial competitiveness and productivity enhancement in developing economies.

Keywords: Case study; Competitiveness; Industries; Metal-mechanical sector; Productivity.

1 INTRODUCTION

Since the liberalization of the Brazilian market in 1990, exemplified by the implementation of the "Plano Brasil Novo," Brazilian industries have faced the imperative of modernization to maintain competitiveness against imported goods (Quinzani, 2021). The economic landscape during the 1990s and early 2000s saw significant growth; however, the past 15 years have been marred by political and economic fluctuations that have severely impacted the productive sector (Mantoan *et*

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al., 2021; Costa, 2020). Critical events such as the global financial crisis of 2008, the impeachment of the president in 2016, the truck drivers' strike in 2018, and the recent COVID-19 pandemic have compounded these challenges.

As of 2021, Brazil ranks among the largest economies globally, yet it remains heavily reliant on the primary sector. The primary exports—commodities such as minerals, meat, and grains—often carry low added value compared to industrialized products incorporating advanced technologies. This situation stems partly from a historical trend of underinvestment in science, technology, and innovation. Brazil's earlier competitive advantage in industrialization relied on an import substitution strategy that utilized inexpensive labor while externalizing social and environmental costs. However, this model has not translated into significant productivity gains in the contemporary context, thereby eroding its competitive edge (Mota Junior, 2018; ASMETRO, 2023).

This predicament has been a focal point of discussion across various media. For instance, Canzian (2024) notes in Folha de São Paulo that Brazilian productivity is only one-quarter that of the United States. Additionally, data from the International Institute for Management Development (IMD, 2024) rank Brazil 62nd out of 67 countries in competitiveness, further corroborating the severity of the issue.

In contrast to these trends, there has been a marked increase in scientific research aimed at enhancing productivity, reducing waste, and improving processes within Brazilian companies. Recent studies emphasize the necessity of implementing strategies such as production process balancing, waste reduction through quality management tools, and the adoption of Lean Manufacturing (LM) principles to enhance productivity and minimize waste across various sectors in Brazil (Teixeira *et al.*, 2022; Teixeira; Teixeira, 2023). This juxtaposition raises a critical question: “Why do Brazilian companies continue to struggle with competitiveness and persistently low productivity despite the adoption of these practices?”

The primary aim of this study is to explore the underlying reasons for this paradox, specifically focusing on the issue of low productivity. A sample of 12 medium-sized enterprises within the metalworking sector will serve as the control group, providing initial insights into their approaches to productivity challenges.

However, the research process has illuminated significant challenges inherent in conducting case studies across multiple firms and in collecting robust qualitative and quantitative data. Therefore, in addition to analyzing productivity within this group of companies, this paper will document the difficulties encountered in executing studies of this nature.

2 LITERATURE REVIEW

2.1 Business competitiveness

The Brazilian Service Support for Micro and Small Enterprises (SEBRAE, 2023) defines industrial competitiveness as the pursuit of customers and new markets among competitors, enabling differentiation through the application of various competitive strategies to enhance advantages and maximize profits. This definition aligns with that provided by the Organization for Economic Co-operation and Development (OECD), as noted by Vieira, Pereira, and Gomes (2017).

Throughout the history of management, numerous theories and a comprehensive definition of business competitiveness have been explored; however, a universal consensus has yet to be reached, as emphasized in the work of Vieira, Pereira, and Gomes (2017).

Several authors have sought to define the concept of strategy, each highlighting different aspects and perspectives. Henderson (1989) posits that strategy is the development and practical implementation of an action plan aimed at achieving a competitive advantage for the business while consistently creating value for the customer and, where possible, reducing costs—whether transactional or operational—without compromising quality. Similarly, Mintzberg, Ahlstrand, and Lampel (2000) emphasize that strategy should involve the formulation of a plan of action to positively shape the future and meticulous monitoring of the execution of that plan.

According to Porter (1996) and Carvalho and Laurindo (2010), competitive strategy can be influenced by the selection of a unique value position combined with an internal arrangement of activities that allow a company to distinguish itself from its competitors, thereby establishing a prominent strategic position. This entails adding greater value to the product or service offered to consumers based on factors such as the threat of substitute products, the threat of new entrants, the bargaining power of customers, the bargaining power of suppliers, and the rivalry among existing competitors—collectively known as "Porter's Five Forces."

Finally, the National Confederation of Industry (CNI, 2017) asserts that competitiveness is quantified and qualified using performance indicators and determinant indicators. The former primarily refers to gross results, while the latter indicates the competitive potential of an

organization. Understanding these indicators facilitates informed political and economic decision-making to ensure the maintenance of competitiveness. Figure 1 provides a summary of this topic.

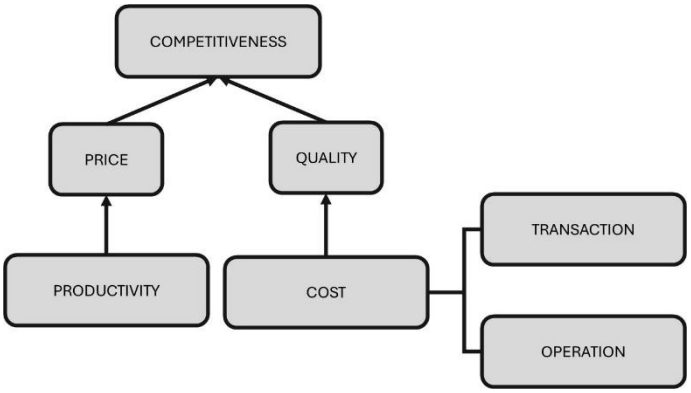

Figure 1 - Diagram illustrating the determining factors for ensuring competitiveness
Source: CNI (2017).

2.2 Productivity

According to Lopes, Fernandes, and Barbosa (2016), the performance of organizations, countries, and regions directly depends on productivity, which is used to measure competitiveness, performance, growth, and profitability. In industry, productivity refers to the ability to deliver products and services with maximum efficiency. Ideally, productivity should equal a value of one when total outputs are divided by total inputs, thereby measuring the effectiveness of the production effort.

In the industrial context, another productivity indicator may be the number of employees, or the gross measure of hours worked. The latter is often more suitable, as it encompasses production line inconsistencies such as equipment breakdowns, rework, scrap, and shortages of inputs, allowing for comparisons across different contexts, regardless of the work regime (CNI, 2017).

La Falce, De Muylder, and Toivanen (2016) argue that productivity indicators provide insights into the relationship between productivity and economic growth, as well as unit labor costs (ULC). Key indicators include, for example, GDP per capita growth, levels of GDP per capita, labor productivity growth, gross national income, capital and multifactor productivity, and sector-specific productivity growth. In many cases, intangible indicators such as customer capital, innovation capital, and process capital are also used to measure productivity; however, their correct interpretation relies on the experience and insight of the involved managers.

2.3 Production Process Management

Chiavenato (1994) defines production processes as a set of methodologies and procedures that enable the efficient and effective execution of manufacturing, aiming to meet consumer needs. Chiavenato also distinguishes between open and closed production processes. Open, or organic, processes operate under unknown and unpredictable cause-and-effect relationships. In contrast, closed, or mechanical, processes function with predefined cause-and-effect connections, maintaining a constant correlation with the environment.

In this context, Lean Manufacturing (LM) stands as a management methodology that prioritizes optimization, waste identification, and elimination (Hasegawa *et al.*, 2024). LM is directly derived from research conducted by Womack, Jones, and Ross at the Massachusetts Institute of Technology (MIT), intended to elucidate the success of Japanese companies in the global market, resulting in the book The Machine That Changed the World (Womack; Jones; Ross, 1992).

The success of LM is strongly linked to market demands, as it strives for high-quality products, competitive prices, and shorter lead times. Correctly interpreting this scenario begins with understanding production as a network of interconnected processes and operations, forming a comprehensive system that is always open to improvement. Achieving this goal requires rigorous monitoring of the production process, where improvement opportunities should be identified from the start of the supply chain. This includes the systematic elimination of waste and non-value-added processes within the chain and the product, thereby making management more focused and efficient to achieve these results (Iranmanesh *et al.*, 2019; Pereira *et al.*, 2019).

Finally, it is essential to note that, over time, LM has proven to be a robust management philosophy, leading many companies worldwide to adopt or adapt these principles. With the

introduction of Industry 4.0 concepts in organizations, studies by Mrugalska and Wyrwicka (2017) and Pereira *et al*. (2019) highlight a strong strategic connection between LM and Industry 4.0, demonstrating that this management method is both relevant and well-suited to the current industrial context.

3 METHODOLOGY

According to Gil (2002) and Yin (2015), this study is classified as exploratory research, employing both qualitative and quantitative methods through content analysis. Data collection was conducted using semi-structured interviews with company managers to gather data and evidence to address the formulated hypotheses.

Twelve medium-sized companies in the metal-mechanic sector were selected for the study. These companies were chosen based on previous Final Projects (TCCs) developed at a federal university in the state of Minas Gerais, focusing on productivity improvement. These projects were defended before a panel between 2017 and 2019. Among the companies surveyed, three are in the metropolitan region of Belo Horizonte in Minas Gerais, four in the metropolitan region of São Paulo, and five in the interior of the state of São Paulo.

Companies were selected based on specific criteria: (i) belonging to the metal-mechanic sector; (ii) classification as medium-sized companies according to SEBRAE (2024); (iii) completion of Final Projects in engineering at a university campus in the state of Minas Gerais; and (iv) a focus on case studies related to productivity enhancement. These criteria were essential to establish a control group, minimizing variation by concentrating on a specific subset. In 2023, interviews with managers of these 12 companies were conducted via telephone or videoconference, collecting data on the application of techniques and tools aimed at productivity improvement and assessing their effectiveness.

4 RESULTS AND DISCUSSION

This analysis presents a comprehensive examination of the varied implementation statuses, challenges, and impacts of continuous improvement methodologies within medium-sized metal-mechanic companies in Brazil. External factors—particularly the COVID-19 pandemic and corporate restructurings—played a notable role in shaping the outcomes of these methodologies, with both direct and indirect effects on productivity, continuity, and overall organizational commitment to improvement practices. The case study approach, as discussed by Costa, Alexandre *et al*. (2013), Yin (2015), and Zomer (2017), is well-suited for such an exploration, providing a structured means to investigate complex and contemporary phenomena where the boundaries between cause and effect are often unclear. This approach, combining qualitative and quantitative insights, allows for an in-depth analysis of these companies' continuous improvement journeys, capturing the multifaceted nature of their operational challenges and the contextual factors that influence them.

In a sector marked by low productivity and competitiveness, Brazilian companies—particularly those within the medium-sized, metal-mechanic sector—face unique challenges. The study focused on 12 companies that meet SEBRAE (2024) criteria for medium size, employing at least 100 individuals and reporting annual revenues between 16 and 90 million BRL. This sector selection underscores a segment of the Brazilian economy that plays a critical role in industrial development yet struggles to maintain competitive productivity standards. The study's objective goes beyond numerical data analysis, seeking instead to identify and understand the variables that impact productivity and competitiveness within these companies, offering a comprehensive view of the specific factors that affect this group.

As detailed in Chart 1, the initial conditions and characteristics of these companies at the time of their Final Projects (TCCs) provide foundational insights into their operational baselines. Each TCC was rooted in the application of Lean or continuous improvement methodologies—such as PDCA, Value Stream Mapping (VSM), and Six Sigma—reflecting the strong influence of Lean principles like those popularized through the Toyota Production System (TPS). These approaches are widely regarded for their ability to reduce waste, improve flow, and increase operational efficiency (Womack; Jones; Ross, 1992; Iranmanesh *et al*., 2019). The TCC projects were completed between 2017 and 2020, offering a longitudinal perspective on the impact of continuous improvement initiatives over time, especially as they were impacted by external disruptions like the pandemic.

The data collection process involved direct engagement with TCC authors or, where unavailable, interviews with managers responsible for these projects. This qualitative approach allowed for a nuanced understanding of how Lean methodologies were applied, the specific challenges encountered, and the organizational dynamics affecting productivity outcomes. Findings indicate

that cultural resistance, inconsistent management support, and operational disruptions were common obstacles, aligning with Womack *et al.*'s (1992) and Iranmanesh *et al.*'s (2019) observations on the crucial role of sustained managerial commitment and organizational alignment in achieving lasting improvements through Lean practices.

This study's value lies in its detailed documentation of real-world productivity challenges and the contextual limitations faced by these companies, particularly under the pressure of unforeseen external factors like the COVID-19 pandemic. As such, this research contributes to the growing body of knowledge on continuous improvement within the context of Brazilian medium-sized industries, providing insights that could inform future implementations of Lean and other productivity-enhancing methodologies in similar environments.

CHART 1 - Overview of Initial Conditions of Selected Companies

Company	Location	Revenue*	TCC Topic
BH-M1	Metropolitan Belo Horizonte	R$16.0 to R$19.5 Million/year	Implementation of the Plan, Do, Check, Act (PDCA) cycle and Value Stream Mapping (VSM) in a company sector (2020)
BH-M2	Metropolitan Belo Horizonte	Approximately R$22.5 Million/year	Use of Lean Manufacturing (LM) to optimize material movement to increase productivity (2019)
BH-M3	Metropolitan Belo Horizonte	R$16.0 to R$25.0 Million/year	Application of Single Minute Exchange of Die (SMED) and creation of an Overall Equipment Effectiveness (OEE) indicator (2018)
SP-M1	Metropolitan São Paulo	R$22.5 to R$26.5 Million/year	Reduction of defects and rework using Six Sigma (6σ) and poka-yoke systems (2017)
SP-M2	Metropolitan São Paulo	Approximately R$19.5 Million/year	Implementation of Value Stream Mapping (VSM) to reduce the lead time of a product family (2017)

*Values approximate and reported by the company when the TCC was finalized.
Source: Author data (2024).

Chart 1 provides a detailed overview of the companies' initial conditions at the time their respective Final Projects (TCCs) were completed, capturing critical information about location, annual revenue, and the main focus of each TCC. This foundational data reveals both the diversity and the common themes within these companies' approaches to productivity improvement. Notably, the majority of TCC topics revolved around Lean Manufacturing principles, including PDCA cycles, Value Stream Mapping (VSM), Single Minute Exchange of Die (SMED), and Six Sigma (6σ) methodologies. Such focus reflects the widespread influence of the Toyota Production System (TPS), a pioneering Lean framework developed by Toyota and subsequently adopted across global industries for operational efficiency and waste reduction (Womack; Jones; Ross, 1992; Iranmanesh *et al.*, 2019).

Each project's scope and timeline offer insights into these companies' specific productivity needs and capabilities. For instance, BH-M1 implemented the PDCA cycle and VSM in 2020, likely targeting incremental improvement and operational visibility in a specific sector. Meanwhile, BH-M2 pursued material movement optimization through Lean Manufacturing in 2019, highlighting the ongoing focus on productivity enhancements in high-movement environments. Similarly, BH-M3 and SP-M1 employed SMED and Six Sigma/poka-yoke, respectively, aimed at reducing setup times and minimizing defects and rework. The initiatives of SP-M2—focused on VSM to streamline lead times—align with broader Lean objectives to enhance responsiveness and reduce cycle time, aligning with findings by Womack *et al.* (1992) on the impact of Lean tools in reducing inefficiencies and improving flow.

Conducted interviews with project authors (or their respective managers) provided additional context for these initiatives. Each participant shared insights into the applicability, challenges, and initial outcomes of the productivity tools implemented, helping to validate findings and align them with current production engineering perspectives on Lean Manufacturing and productivity methodologies.

CHART 2 - Qualitative Summary of Managerial Insights from Interviews

Company	Direct Contact with TCC Author?	Productivity Issues?	Competitiveness Issues?	TCC Proposal Implemented?
BH-M1	Yes	Yes	Yes	Partially
BH-M2	No	Yes	Not Disclosed	No
BH-M3	No	No	Yes	No
SP-M1	Yes	Yes	Yes	Yes

Source: Author data (2024).

Chart 3 further details the main points from each interview concerning productivity and operational efficiency improvements.

CHART 3 - Manager Perceptions of Productivity Drivers

Company	Key Interview Highlights
BH-M1	1. PDCA and VSM were applied from 2020 to 2021; 2. Implementation ceased due to the pandemic; 3. Lack of commitment to cultural change.
BH-M2	1. The manager disclosed limited information; Lean Manufacturing was replaced with Lean Six Sigma with limited success; 2. High employee turnover remains an issue in 2023.
BH-M3	1. SMED implementation was discontinued; 2. Operational restructuring due to the pandemic halted the program.
SP-M1	1. Rework and defect reduction were achieved, with 6σ and poka-yoke successfully implemented; 2. No further details due to industrial confidentiality.

Source: Author data (2024).

The analysis of Chart 2 highlights the level of engagement, productivity, and competitiveness concerns across different companies. Among the interviewed companies, BH-M1 and SP-M1 showed active direct engagement with the TCC author and displayed both productivity and competitiveness concerns. Notably, SP-M1 fully implemented the TCC proposals, while BH-M1 did so only partially. In contrast, BH-M2 and BH-M3 faced notable limitations. BH-M2 revealed issues related to productivity but chose not to disclose competitiveness details and did not implement the TCC recommendations, while BH-M3 showed no productivity issues but acknowledged competitiveness challenges. This selective engagement in improvement initiatives aligns with the literature on resource prioritization in competitive environments, as indicated by Womack, Jones, and Roos (1992) in their discussion on Lean transformations.

In Chart 3, deeper insights emerge regarding productivity drivers, revealing diverse approaches and varying levels of success in adopting Lean and other continuous improvement tools. BH-M1 attempted the PDCA cycle and Value Stream Mapping (VSM) from 2020 to 2021, though these were discontinued due to pandemic-related disruptions and a lack of commitment to cultural change, echoing Iranmanesh *et al.*'s (2019) findings on cultural resistance as a major obstacle. BH-M2 shifted from Lean Manufacturing to Lean Six Sigma with only limited success, as high employee turnover impacted the implementation process in 2023. Meanwhile, BH-M3 attempted to implement SMED, yet operational restructuring halted progress—a trend also noted by Iranmanesh *et al.* (2019) regarding managerial commitment in sustaining Lean initiatives.

SP-M1 presents a more favorable outcome, with successful reductions in rework and defects achieved through Six Sigma and poka-yoke methods, though further details were withheld due to confidentiality concerns. This outcome underscores the potential of structured Lean tools to yield results in rework reduction and defect minimization, as illustrated in Womack *et al.*'s (1992) framework for competitive advantage through Lean practices.

The interviews collectively indicate that while companies like BH-M1 and SP-M1 attained significant progress, others faced barriers such as cultural resistance, limited managerial commitment, and operational disruptions exacerbated by the COVID-19 pandemic. As summarized in Chart 3, sustained support from top management and a conducive organizational culture are critical to overcoming these barriers and achieving effective productivity improvements. These findings reinforce existing research by Womack *et al.* (1992) and Iranmanesh *et al.* (2019), emphasizing the crucial role of consistent managerial support and cultural alignment in the successful application of Lean principles in competitive manufacturing environments.

This qualitative analysis underscores the importance of addressing organizational culture and sustained managerial support for productivity initiatives, as echoed by previous studies on Lean and productivity improvements in competitive manufacturing contexts (Womack; Jones; Ross, 1992; Iranmanesh *et al.*, 2019).

4.1 Individual Company Analysis

Upon analyzing Chart 1 and Chart 2, it was observed that the interviewees provided limited data and information, restricting the scope of the study. In four instances, managers withheld comments about processes and declined to share further details due to "industrial secrecy," even with confidentiality agreements offered and the option to apply legal mechanisms to ensure confidentiality. Nonetheless, an individual analysis was conducted for each company, summarizing qualitative data and insights.

4.2 Company BH-M1

This organization engaged in a capstone project in early 2020 focusing on the implementation of the Plan-Do-Check-Act (PDCA) cycle, a four-step iterative process commonly used for quality improvement (Deming, 1986), alongside Value Stream Mapping (VSM), which helps visualize and improve production flow by mapping all necessary steps and identifying inefficiencies (Rother; Shook, 1999). Post-pandemic, the company faced material shortages but continued to apply PDCA and VSM in the case study sector. However, senior management discontinued VSM and PDCA in other sectors, citing high existing productivity levels as justification. According to the interviewee, the company still experiences productivity-related issues, such as overtime due to scrap and rework, customer lead-time delays, and increased product costs, which ultimately reduce competitiveness against industry rivals.

4.3 Company BH-M2

In this company, the 2019 capstone project explored Lean Manufacturing (LM) to optimize material handling and boost productivity. Lean Manufacturing, which emphasizes waste reduction and efficient resource use (Womack; Jones, 1996), was later replaced in 2022 by Lean Six Sigma. Lean Six Sigma, integrating lean efficiency principles with Six Sigma's data-driven focus on process variability reduction (George *et al.*, 2004), has since provided more robust statistical insights and production tracking. The manager cited ongoing challenges, including resistance to change and management limitations, but noted that the company's productivity and competitiveness remain on par with key competitors, though far from optimal.

4.4 Company BH-M3

In 2018, a capstone project in this organization applied Single Minute Exchange of Die (SMED), aimed at reducing setup times to improve flexibility and efficiency (Shingo, 1985), along with establishing an Overall Equipment Efficiency (OEE) indicator to measure productivity (Nakajima, 1988). Both initiatives were subsequently abandoned due to the pandemic and the company's acquisition by an investment group in 2021, which led to new production management strategies. According to the manager, the company faces intense internal and external competition, remaining productive yet struggling to sustain competitiveness. The pandemic has been highlighted as a critical factor in management's strategic redirection.

4.5 Company SP-M1

This company completed a capstone project in late 2017 to minimize scrap and rework using Six Sigma (6σ), a data-driven methodology to enhance process capability and quality (Harry; Schroeder, 2000), combined with poka-yoke systems, which aim to prevent errors through design (Shingo, 1986). Despite data confidentiality concerns, the interviewee confirmed that the processes were effective and have been adopted across the production line, yielding sustained productivity and competitiveness.

4.6 Companies SP-M2, SP-M3, SP-M4, SP-IN2, and SP-IN3

Representing approximately 42% of the total, these companies either provided minimal information or were unavailable for interviews. Notably, the SP-M2 manager confirmed that Value Stream Mapping (VSM), implemented in a 2017 capstone project to reduce lead time for a product

family, remains in use for process mapping. The pandemic significantly impacted management practices across these companies, prompting a shift in operational strategies.

4.7 Company SP-IN1

This organization completed a project in 2017 focusing on the 5S methodology, a foundational Lean tool that promotes workplace organization through five principles: Sort, Set in order, Shine, Standardize, and Sustain (Osada, 1991). Initially effective, 5S lost momentum over time due to insufficient support from upper management and employees. Although specific metrics were not disclosed, the interviewee noted challenges in maintaining 5S and other Lean tools amidst positive market performance, which upheld productivity and competitiveness levels as of 2023.

4.8 Company SP-IN4

Like BH-M1, this company reported using OEE with automated systems, displaying real-time productivity indicators through a digital dashboard. Despite five years of application, OEE remains at 63%, below the "world-class" benchmark of 85% (Nakajima, 1988). Key obstacles include a lack of 5S and Total Productive Maintenance (TPM) adherence, as well as workforce resistance. While a leader in its sector, the company paradoxically experiences low productivity and compensates with overtime and Saturday shifts to meet demand.

4.9 Company SP-IN5

This organization implemented Lean Manufacturing principles in a 2019 capstone project to optimize a truck maintenance workshop within a logistics center. After forming a joint venture with a larger firm, Lean Manufacturing has become a core requirement to align all plants with standardized processes and meet reduced lead-time expectations. The manager reported industrial confidentiality constraints but noted that low productivity and competitiveness challenges persist, despite support from the multinational partner.

5 CONCLUSION

This study aimed to explore and analyze the critical factors affecting productivity within Brazilian companies by establishing a control group. Despite facing limitations such as a limited number of participating companies and the scarcity of comprehensive data provided by respondents, the research yielded valuable qualitative insights. These findings illuminate the multifaceted challenges these organizations encounter, serving as a foundation for formulating hypotheses regarding their productivity issues.

The research underscores the inherent difficulties in conducting case studies within industrial settings, particularly the challenge of obtaining robust quantitative data essential for conclusive analysis. This experience illustrates the urgent need for enhanced methodological approaches that foster greater corporate collaboration and improve the quality of data collected. Such improvements can significantly contribute to identifying operational inefficiencies and assist in developing effective solutions for production and business challenges.

Several key observations emerged from this study. Notably, a significant portion of the participating companies expressed reluctance to share information, primarily due to concerns regarding industrial confidentiality. This finding is not uncommon in industrial research, where competitive advantage often discourages companies from disclosing proprietary data. Furthermore, the data provided was largely qualitative, which limited the precision of hypothesis generation and impeded a thorough technical analysis. Even with confidentiality agreements and ethical protocols in place, the hesitance to share detailed information indicates a broader trend that can hinder research outcomes.

The principal findings of this study can be summarized as follows:

1. Reluctance of companies to provide data and information.
2. The detrimental impact of the COVID-19 pandemic on ongoing improvement efforts.
3. Challenges in sustaining initially successful improvement programs over time.
4. The necessity for cultural alignment across organizational hierarchies to foster a culture of continuous improvement.
5. The imperative for increased support from senior management to initiate and maintain improvement programs.
6. Ongoing challenges faced by companies in maintaining productivity and competitiveness.

Despite the study's limitations, the findings indicate that the control group, although operating

in geographically diverse regions, faced analogous challenges concerning productivity and competitiveness. These issues highlight the struggle to establish and sustain effective improvement programs aimed at enhancing overall process and business performance. Such difficulties can be significant contributing factors to the observed low levels of productivity and competitiveness within the studied organizations, as they grapple with inconsistencies in their organizational standards, control mechanisms, and the implementation of methodologies. Additionally, there are notable challenges in transforming mindsets at all levels, particularly among senior management.

In line with the insights of Mrugalska and Wyrwicka (2017) and Pereira *et al.* (2019), Brazilian companies must undergo a profound mindset transformation and adopt innovative practices to enhance their competitive positioning and effectively implement Industry 4.0 strategies. This transformation is particularly urgent, given that micro, small, and medium enterprises (MSMEs) constitute 99% of the companies in Brazil, representing over 54% of private-sector formal employment, according to SEBRAE (2024). Therefore, bolstering the productivity and competitiveness of these enterprises is vital for stimulating Brazil's economy and supporting both local and multinational operations.

The managerial models and techniques discussed throughout this study are pivotal in understanding productivity challenges and formulating viable solutions.

1. Plan-Do-Check-Act (PDCA) Cycle: This iterative framework is essential for continuous improvement, allowing organizations to evaluate changes on a small scale, monitor results, and refine processes based on observed outcomes (Deming, 1986). By fostering a culture of systematic learning and adaptation, the PDCA cycle equips companies to respond effectively to operational challenges.

2. Value Stream Mapping (VSM): As a critical tool in lean management, VSM aids in identifying value-added versus non-value-added activities, facilitating the optimization of production processes (Rother; Shook, 1999). By visualizing workflows, organizations can enhance efficiency and reduce waste, thereby improving overall productivity.

3. Lean Manufacturing: This philosophy emphasizes the elimination of waste while maximizing value for customers. By focusing on streamlining operations, Lean Manufacturing techniques can significantly enhance productivity and efficiency (Womack; Jones, 1996). Companies that adopt lean principles can cultivate a mindset centered on continuous improvement, driving long-term success.

4. Lean Six Sigma: This methodology combines the waste-reduction principles of Lean Manufacturing with the statistical rigor of Six Sigma to improve process quality and reduce variability (George *et al.*, 2004). By fostering a data-driven approach to problem-solving, Lean Six Sigma enables organizations to achieve higher productivity levels while maintaining quality standards.

5. Total Productive Maintenance (TPM): TPM fosters a proactive maintenance culture by involving employees in the care and maintenance of equipment (Nakajima, 1988). This approach not only extends equipment lifespan but also enhances operational efficiency, ultimately contributing to improved productivity outcomes.

6. 5S Methodology: This system promotes workplace organization and efficiency through the implementation of five principles: Sort, Set in order, Shine, Standardize, and Sustain (Osada, 1991). By establishing a clean and organized work environment, organizations can reduce waste, enhance safety, and improve productivity.

These models and techniques provide a framework for addressing the challenges identified in this study. Their successful implementation can help organizations build a culture of continuous improvement, drive efficiency, and enhance overall competitiveness.

The lack of literature addressing the limitations and challenges of conducting studies in this domain is noteworthy. Future research should focus on developing methodologies that enable researchers to collect robust data and comprehensive information effectively. Moreover, it is imperative to explore the root causes of low productivity and competitiveness in specific sectors. Tailored solutions that consider the unique characteristics of different industrial activities must be identified to facilitate meaningful improvements.

By addressing these research gaps and implementing the discussed managerial techniques, Brazilian companies can enhance their operational capabilities and better navigate the complexities of the modern industrial landscape. This strategic approach will not only contribute to improved productivity and competitiveness but also support the broader goal of strengthening Brazil's economic position in the global market.

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