

Data-driven strategies for service efficiency and spare parts management in injection moulding maintenance

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Abstract. *Service operations' quality and efficiency play an essential role in reducing downtime, optimizing costs and improving customer satisfaction in industrial moulding maintenance. Workforce productivity and effective intervention are crucial for maintaining a high level of service performance and continuous operations. This paper studies the correlation between service productivity, spare parts sales and total company revenue, using financial data collected from a technical department of a company specializing in industrial machinery. The methodology includes a case study, using correlation matrix and quality management instruments such as FMEA analysis and Ishikawa diagram in order to identify KPIs (key performance indicators) and improvement strategies. Furthermore, the study examines how improved resource allocation, structured intervention scheduling and reduction of non-billable hours support the enhancement of service profitability. The findings of the research provide actionable insight into optimizing service operations, strengthening financial performance and ensuring better customer satisfaction.*

Keywords: Service productivity, spare parts sales, FMEA, Ishikawa, industrial engineering, optimization, KPIs

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Introduction

The industrial injection moulding equipment domain is characterized by high-cost equipment and significant financial impact generated by unplanned downtime. In this context, efficient maintenance services and optimized spare parts management are essential for reducing operational disruptions and ensuring long-term equipment performance.

The economic importance of industrial maintenance goes beyond simply ensuring operational continuity; it represent a vital profit center that directly contribute to a company's financial health and market position. [1] After sales services and after market support constitute substantial revenue streams for industrial companies, including field technical assistance, spare parts distribution and customer support services. [2] The project growth of the maintenance services market further underscores the increasing economic importance of this sector, with a compound annual growth rate (CAGR) of 10,4% estimated between 2025 and 2034. [3] This evolution confirms that strategic investment in this area is not just a cost-reduction measure, but a significant growth opportunity.

Fluctuations in service revenue indicate inconsistencies in demand, resource allocation, or operational efficiency. A major challenge in the inherent unpredictability of spare parts demand, which necessitates continuous review and adaptation of stocking and supply policies. [4] This external demand volatility is exacerbated by bureaucratic internal processes and delays in sourcing critical components, which negatively impact service response times. The interaction between external demand volatility and internal operational rigidities creates a complex environment for service and spare part management, directly undermining revenue stability and customer satisfaction. This problem is systemic, requiring integrated solutions that address both internal process optimization and external market representatives.

The ISO 9001 standard emphasizes the necessity of establishing measurable objectives, continuous performance monitoring and the use of factual evidence process evaluation and improvement, as detailed in Clause 9.11. Its core principles, including customer focus and continual improvement, can foster innovation and enhance organizational knowledge. [5] ISO 9001 has been implemented by over one million organizations across 187 countries. [5]

This paper aims to analyze the complex relationship between service productivity, spare parts sales, and total company revenue, utilizing financial data from a service department specializing in industrial equipment. It also investigates the influence of ISO 9001 quality management principles and explores how structured intervention planning, reduction of non-billable hours, and improved resource allocation contribute to increased service profitability. The research findings are intended to provide actionable insights for optimizing service operations, leading to increased customer satisfaction and consolidated financial performance.

The primary research question investigates the extent to which service productivity metrics and spare parts sales performance correlate with total organizational revenue in the industrial machinery service sector. A secondary question examines the primary operational inefficiencies affecting spare parts inventory management and service delivery within the organization under analysis. The study also seeks to determine how quality management tools, specifically Ishikawa diagrams and Failure Mode and Effects Analysis (FMEA), can be applied to formulate actionable strategies that enhance service efficiency and profitability. Finally, the research explores strategic interventions that align with ISO 9001 principles and incorporate predictive maintenance technologies to optimize service operations and improve financial performance.

Literature review

The literature extensively explores various facets of service efficiency, spare parts management and the application of quality management tools in industrial settings.

Research consistently highlights the economic importance of service productivity management across industries. Studies indicate that companies actively managing productivity are more successful, with a significant positive effect on business outcomes, particularly in the industrial sector where such practices have been more recently adopted. [6] Productivity, defined as the ratio of output in input, is a fundamental measure of economic performance and improvements in service industries are crucial for overall economic growth. Methodologies like Lean Six Sigma have demonstrated success reducing process variability and waste, leading to improved quality, efficiency, customer satisfaction and cost savings. [7]

The transition from reactive to data-driven Predictive Maintenance (PdM) is a critical element in modern industrial service efficiency, utilizing sensors, IoT, and machine learning to enable condition-based maintenance (CBM) strategies. [8] Furthermore, the complexity of spare parts logistics, particularly managing volatile demand, necessitates data-driven methodologies for continuous review and adaptation of supply chain configurations. [9]. A contemporary strategy involves the targeted application of Additive Manufacturing (AM) for a small fraction of specialized, long-lead-time Stock Keeping Units (SKUs) to unlock significant cost savings and mitigate lead time risks. [10]

ISO 9001 is a globally recognized standard for quality management systems, adopted by over a million organizations worldwide. [5] It provides a structured framework for ensuring products and services meet customer requirements and for continuous improvement. The standard has evolved, with the 2000 version combining previous iterations and focusing on a process approach and customer satisfaction, while the 2015 version emphasizes risk identification and top management involvement. [11] While ISO 9001 generally fosters product innovation, particularly incremental improvements, some studies present contradictory findings, suggesting it might hinder radical innovation due to its focus on standardization and risk aversion. [5] Nevertheless, ISO 9001 certification offers tangible benefits, including improved client appeal, enhanced operational efficiency, and the establishment of robust quality systems. It also aids in addressing quality issues, accelerating legal compliance, providing traceability, fostering staff pride, and ensuring sustainable quality by embedding quality assurance into systemic processes rather than relying solely on individuals.[12]

The Ishikawa diagram is a widely used quality management tool for systematically identifying the root causes of problems. [13] It visually organizes potential causes into categories such as Methods, Manpower, Materials, Machines/Equipment, and Management (the 5Ms).[13] This structured approach facilitates comprehensive problem analysis and encourages teamwork. [5] Similarly, Failure Mode and Effects Analysis (FMEA) is a structured methodology for identifying and prioritizing potential failures in a process, product, or service. It is crucial for proactive quality management under ISO 9001:2015's risk-based thinking. [14]

Methodology

The study adopted a case study methodology, analyzing service data collected from a company in the injection moulding machinery sector. The data was organized into structured tables in Excel. This approach allows for an in-depth investigation of complex phenomena in their real-world context, providing a rich understanding of operational dynamics.

To identify the relationships between key performance indicators (KPIs), such as service productivity, spare parts sales, and overall company performance, correlation analysis was applied. The analysis was conducted in accordance with ISO 9001 guidelines, integrating essential quality management tools. These tools include the Ishikawa diagram (cause-and-effect diagram or fishbone diagram) for root cause analysis and failure mode and effects analysis (FMEA) for risk assessment.

Data collection was based on the company's service department's records, organized into structured Excel tables. The dataset included an overview of the evolution of spare parts and service revenue over six years, illustrating the service department's share in total company revenue. This approach allowed for a detailed analysis of process stability, demand fluctuations, and the effectiveness of maintenance strategies.

Results and further discussions

SWOT analysis

From the extended SWOT analysis, only the most relevant and strategic elements have been retained to capture the company's position in the injection moulding machinery sector. Among the strengths, notable are the presence of a highly qualified engineering team, the integration of advanced automation and IoT solutions, and strong interdepartmental collaboration. The key weaknesses include slow internal procedures for spare part acquisition and the ongoing need for personnel upskilling. Identified opportunities relate to the implementation of preventive and predictive maintenance, entry into emerging markets, and the adoption of energy-efficient technologies. At the same time, threats arise from low-cost competitors, risks of technological obsolescence, and global economic instability. This focused selection ensures that strategic decisions are informed by the most impactful internal and external factors.

Data collection and processing

Based on the data collected, the service department's combined revenue, which includes both service and spare parts sales, consistently accounted for 10% to 15% of the company's total sales in the years preceding 2024. This revenue stream served as a secondary, yet important, component of the overall business performance.

A detailed examination of the data reveals a significant strategic shift in 2024. As presented in Table 1, while the service department's total revenue surged to a historical high (index of 144.58), this was accompanied by an unprecedented decline in the company's total revenue (index of 86.17), which was nearly half of the previous year's total. This anomaly indicates a significant market downturn affecting the core business of new equipment sales. In this context, the service department's revenue, primarily driven by a substantial increase in spare parts sales (from an index of 117.46 in 2023 to an index of 167.00 in 2024), demonstrated remarkable resilience. The service department's share of total company sales peaked at an anomalous 25.08%, underscoring its role as a crucial stabilizing force during periods of corporate-wide financial stress. This finding elevates the discussion from simple operational efficiency to a core business strategy, demonstrating that the company's future financial health is increasingly dependent on the profitability and growth of its after-sales services, especially spare parts.

Table 1: Normalized financial performance metrics (2019-2024)

Year	Spare parts sales (Index, 2019=100)	Service (Index, 2019=100)	Total dept. service (Index, 2019=100)	Company total (Index, 2019=100)	Share of dept. service sales in total sales	Share of spare parts sales in total sales
2019	100,00	100,00	100,00	100,00	0,15	0,0991
2020	95,81	66,00	85,76	89,81	0,14	0,1057
2021	112,90	122,90	115,63	139,74	0,12	0,0794
2022	45,86	107,13	66,51	100,62	0,10	0,0452
2023	117,46	134,12	123,08	173,42	0,11	0,0671
2024	167,00	100,58	144,58	86,17	0,25	0,1920

Source: Authors' own research.

Analysis of engineers' productivity reveals fluctuations in workload. Table 3 highlights the annual work hours per employee, number of employees, and billable efficiency. The findings indicate that optimizing intervention scheduling and reducing non-billable hours can significantly enhance profitability.

Table 2: Annual work hours per technician

Year	Annual work hours	Number of employees	Total hours/ year/ number of employees	Max. hours availability/ engineer	Productivity
2019	10,412	13	801	1,111.33	72.07%
2020	7,378	11	671	1,111.33	60.35%
2021	10,221	9	1,136	1,111.33	102.19%
2022	9,052	9	1,006	1,111.33	90.50%
2023	11,454	9	1,273	1,111.33	114.52%
2024	10,256	9	1,140	1,111.33	102.54%

Source: Authors' own research.

The maximum yearly hour availability was determined during a brainstorming session.

The analysis of billable and non-billable hours from 2019 to 2024, as nuanced in table 3, reveals that billable hours consistently remain below 50%, indicating inefficiencies in service operations. The highest efficiency was recorded in 2022 (41.00%), while the lowest was in 2019 (20.46%), demonstrating significant fluctuations in resource utilization. These variations suggest inconsistencies in service planning and personnel allocation affecting overall operational performance. This fundamental contradiction indicates that the problem is not a lack of effort or inherent productivity from the engineers. Instead, a disproportionate amount of their time is consumed by non-revenue-generating activities, representing a failure in operational planning and resource allocation.

Table 3: Annual work hours per technician

Year	Billable hours	Non-billable hours
2019	2,100,73 (20,46%)	8,310,54 (79.82%)
2020	2,129,89 (34,10%)	5,247,97 (65.90%)
2021	3,485,99 (34,10%)	6,735,50 (65.90%)
2022	3,710,70 (41,00%)	5,340,87 (59.00%)
2023	3,541,00 (30,91%)	7,913,00 (69.09%)
2024	4,171,00 (40,67%)	6,085,00 (59.33%)

Source: Authors' own research.

A detailed examination of the spare parts sales metrics, as shown in table 4, reveals a significant degree of volatility, particularly in the Average Order Value (AOV). Between 2019 and 2024, the number of spare parts offers and orders generally increased, with 2024 recording the highest figures: 1,244 offers and 743 orders. The conversion rate fluctuated, peaking at 64.86% in 2021 and stabilizing at 59.73% in 2024.

Table 4: Annual work hours per technician

Year	Total of offers/year	Total of orders/year	Employees	Total offers/ year/number of employees	Conversion rate	Medium order value (eur)
2019	1,176	623	2	588,00	52,98%	1,002,02
2020	984	563	2	492,00	57,22%	1,062,36
2021	942	611	2	471,00	64,86%	1,143,68
2022	1,115	716	2	557,50	64,22%	399,85
2023	1,173	651	2	586,50	55,50%	1,126,35
2024	1,244	743	2	622,00	59,73%	1,402,72

Source: Authors' own research.

Setting Key Performance Indicators (KPIs)

According to ISO 9001:2015, organizations must establish measurable objectives to assess performance, customer satisfaction, and process efficiency. [14] In this study, the main KPIs selected were: K1: service revenue per engineer, K2: billable versus non-billable hours, and K3: conversion rate of spare parts offers to orders. These KPIs were used to analyze trends and assess the impact of various operational improvements.

Correlation analysis

A correlation matrix was constructed, as shown in table 5, to analyze relationships between service efficiency metrics and to identify areas for improvement. The correlations were computed and visualized through a heatmap for better interpretation, helping identify relationships between key business variables and providing insights into service performance trends and improvement areas.

One of the most powerful findings is the very high positive correlation of 0.96 between the overall revenue of the service department and spare parts sales. This indicates that spare parts transactions are a decisive driver of departmental income, affirming the strategic relevance of effective inventory management and streamlined sales processes for sustaining financial performance. Similarly, the strong correlation of 0.88 between engineer productivity and service revenue demonstrates that higher levels of engineer efficiency directly enhance service-related profitability. This evidence reinforces that reducing non-billable time and optimizing intervention planning are crucial levers for increasing revenue generation.

Overall, the analysis identifies two areas with the greatest potential for improvement. The first concerns spare parts sales, which show the strongest correlation with service department revenue. Enhancing this activity could therefore provide immediate and substantial financial benefits. The second relates to engineer productivity, which is closely tied to service revenue generation. While productivity levels are already relatively high, the predominance of non-billable hours—exceeding 50% of total recorded work—represents a major inefficiency. This imbalance highlights a critical opportunity to transform idle capacity into additional revenue through better planning and optimization of internal processes.

Table 5: Correlation matrix

	YEAR	SPARE PARTS	SERVICE	DEPT. SERVICE TOTAL	COMPANY TOTAL
YEAR	1.00				
SPARE PARTS	0.46	1.00			
SERVICE	0.44	0.10	1.00		
DEPT. SERVICE TOTAL	0.55	0.96	0.38	1.00	
COMPANY TOTAL	0.22	0.04	0.82	0.27	1.00

Source: Authors' own research.

Applying the Ishikawa diagram for stabilizing the root causes of inefficiency in spare parts sales

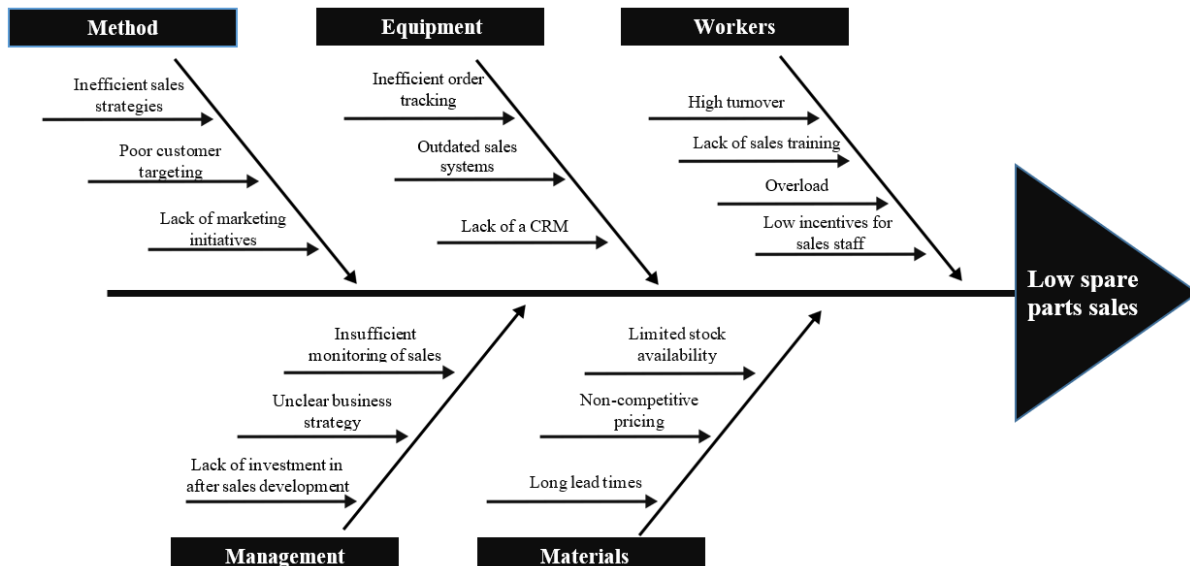


Figure 1: Ishikawa diagram
Source: Authors' own research.

The Ishikawa diagram, also known as the cause-and-effect diagram or fishbone diagram, was developed to systematically identify the root causes of problems in quality management. [13] This tool is widely used within ISO 9001:2015 frameworks for problem-solving and continuous improvement, aligning with clause 10.2, which emphasizes the importance of identifying nonconformities and implementing corrective actions. [14]

The Ishikawa diagram classifies potential causes into main categories, often referred to as the 5M: methods, manpower, materials, machines/equipment, and Management. [13] These categories facilitate a structured and comprehensive analysis of problems. For example, "Methods" refers to procedural inefficiencies, "Manpower" to human resource constraints or skill gaps, "Materials" to issues related to inventory or the quality of spare parts, "Machines/Equipment" to operational systems and workflow inefficiencies, and "Management" to organizational decisions or lack of strategic planning. [15]

A brainstorming with the sales and service teams was conducted to classify the identified problems affecting spare parts sales and operational efficiency. The Ishikawa diagram is shown in picture 3.

Failure mode and effects analysis (FMEA) for spare parts sales issues

Based on the Ishikawa diagram, a Failure Mode and Effects Analysis (FMEA) was performed to quantify the impact of each failure mode and prioritize risks for strategic intervention. This structured approach is used to identify and prioritize potential failures, with its purpose being to prevent defects by analyzing risks and implementing corrective measures before failures occur.

Key components of FMEA include: failure modes, identifying the ways a process can fail; effects analysis, evaluating the impact of each failure mode; severity (S), assessing the seriousness of consequences (scale: 1-10); occurrence (O, scale: 1-10), detection (D, scale: 1-10); risk priority number (RPN), calculated by multiplying the severity, occurrence, and detection values.

The determination of the Severity (S), Occurrence (O), and Detection (D) scores (on a 1-10 scale) was determined through expert judgment provided by the technical team during a dedicated brainstorming session, ensuring that the scoring reflected internal operational context and risk perception as recommended by FMEA methodological guidelines.

As shown in table 6, the analysis indicates that the most critical areas requiring improvement are linked to limited stock availability, high employee turnover, and long lead times. The failure mode of limited stock availability received the highest RPN score of 504, highlighting significant deficiencies in demand forecasting and inventory management.

This shortcoming directly results in missed sales opportunities and customer dissatisfaction, as demonstrated by the 2022 revenue collapse despite a high number of orders. Addressing this issue is the single most critical intervention for future profitability. Furthermore, high employee turnover within the sales team and long lead times each received an RPN of 336. High turnover leads to diminished organizational knowledge and negatively

affects sales performance, while long lead times undermine the company's ability to meet customer requirements in a timely manner. These issues not only create customer dissatisfaction but also erode the company's competitive standing. Finally, the absence of structured training for the salesforce, with an RPN of 294, represents a significant barrier to achieving maximum efficiency. A workforce that lacks adequate skills is less capable of converting leads into sales and providing high-quality customer interactions, which impacts both conversion rates and overall sales revenue.

Table 6: Correlation matrix

Failure mode	Potential effect	S (1-10)	O (1-10)	D (1-10)	RPN	Recommended action
Inefficient sales strategies	Low conversion rates	6	7	5	210	Implement targeted sales strategy
Poor customer targeting	Wasted marketing efforts	5	6	5	150	Use CRM and customer segmentation
Lack of marketing initiatives	Low customer engagement	6	7	5	210	Develop digital marketing campaigns
Inefficient order tracking	Operational delays	6	6	5	180	Implement automated tracking system
Limited stock availability	Delays in service, missed revenue	9	8	7	504	Improve inventory planning and demand forecasting
Long lead times	Customer dissatisfaction, lost sales	8	7	6	336	Strengthening supplier relationships and streamline procurement
Non-competitive pricing	Lower competitiveness, lost opportunities	7	6	6	252	Review and adjust pricing strategy
Outdated sales systems	System inefficiencies	6	5	6	180	Upgrade sales tracking system
Lack of CRM	Missed follow-ups, lost opportunities	7	6	6	252	Invest in CRM and training for the team
High turnover	Employee dissatisfaction, knowledge loss	7	8	6	336	Improve retention strategies and incentives
Lack of sales training	Underperformance in sales	6	7	7	294	Provide structured training programs
Low incentives for sales	Low motivation, lower sales effort	5	6	6	180	Introducing performance-based incentives
Insufficient monitoring of sales	Inefficient tracking of performance	5	5	5	125	Implement structured reporting and KPIs
Unclear business strategy	Lack of direction in decision-making	6	5	6	180	Define and align long-term strategy
Lack of investment in after-sales development	Missed growth opportunities	5	5	5	125	Allocate budget for after-sales initiatives
Non-competitive pricing	Lower competitiveness, lost opportunities	7	6	6	252	Review and adjust pricing strategy

Source: Authors' own research.

Data-driven strategies

The prioritization of operational risks via FMEA establishes three interdependent pillars for strategic proposals, which are substantiated by contemporary academic research. Addressing the critical supply chain risk, Limited Stock

Availability (RPN 504), is optimally managed by the deployment of Machine Learning (ML) for Predictive Demand Modeling, a technique validated to increase inventory allocation accuracy by 13% to 16%. [16] Concurrently, mitigating Long Lead Times (RPN 336) is proposed through proactive, predictive procurement methods, which are expected to yield a 12% improvement in lead time efficiency and achieve 98% On-time Delivery. [17] The final pillar, Human Capital Optimization, is addressed by focusing on High Turnover and Lack of Sales Training (RPN 336/294) via data-driven retention and the integration of the research-backed "Me and AI" hybrid coaching model for enhanced agent skill development. [18] These structural proposals are designed to synchronize logistics, thereby eliminating engineer non-billable time and maximizing the empirically confirmed correlation (0.88) between productivity and service revenue.

Conclusion

The present study confirms that in the industrial injection moulding equipment sector, service operations and spare parts management are not peripheral support activities but strategic levers of growth and financial resilience. The correlation analysis revealed that engineer productivity and spare parts sales are decisive drivers of service department profitability. This was most starkly evidenced by the 2024 data, where the service department acted as a stabilizing force during a corporate-wide financial downturn, a role that elevates its strategic importance.

However, the analysis also exposed systemic inefficiencies, most notably the high prevalence of non-billable hours and the volatility in spare parts sales. Root cause analysis using Ishikawa diagrams and FMEA provided a clear roadmap for improvement, prioritizing the most critical risks, including limited stock availability, high staff turnover, and long lead times.

Based on this diagnostic, the core proposals recommend implementing ML-driven demand modeling to increase inventory allocation accuracy by 13%–16%, along with predictive procurement to improve lead time efficiency by 12%. Furthermore, adopting the "Me and AI" hybrid coaching model and data-driven retention strategies is proposed to mitigate human capital risks. These research-backed interventions offer a direct path to convert operational losses into sustained service profitability.

Future developments and limitations

The primary limitation of this research stems from its single-case study methodology, which utilizes financial and operational data and restricts the generalizability of the findings to the broader injection moulding industry. Future research should prioritize a multi-case study approach to validate the identified correlations and employ longitudinal analysis to assess the long-term impact of the proposed data-driven strategic interventions.

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