

Improvement of the Service Level Through the Implementation of MRP and MPS in a Peruvian Infusion Company

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Abstract

This article addresses the problem of low order fulfillment levels in a Peruvian company dedicated to the production of herbal infusions, caused by the lack of structured planning of materials and processes. The study proposes the design and implementation of an integrated planning system based on MPS and MRP tools, which synchronizes demand, procurement, and production. To achieve this, a process engineering methodology was applied, complemented by statistical analysis and simulation tools to validate the effectiveness of the proposed model. The results show a 13.6% increase in labor productivity, an improvement in the order fulfillment indicator (OTIF) from 80% to 95%, and a significant reduction in stockouts. In addition, positive social effects were observed, reflected in higher employee satisfaction and improved training, thereby strengthening organizational sustainability. In conclusion, the implementation of the MPS-MRP system enhanced operational efficiency, increased profitability, and fostered a work culture based on planning and continuous improvement.

Keywords

Supply chain management; Forecasting models; Master Production Schedule; Material Requirements Planning; Operational efficiency.

1. Introduction

The Peruvian manufacturing sector represents one of the pillars of the national economy, contributing more than 12% to GDP (INEI 2024). In particular, the food and beverage industry faces increasing demands related to the synchronization of demand, procurement, and production, a critical condition for ensuring adequate service levels in Latin American SMEs (Tobón-Valencia, Ospina and Giraldo 2022). In this context, production planning has become a key determinant of operational performance, especially in environments characterized by high uncertainty and supply chain disruptions (Ivanov, 2021), highlighting the need for integrated models that enhance resilience and responsiveness.

The analyzed company, with more than twenty years in the market and a portfolio of 14 product lines, faces recurring difficulties in managing demand, inventory, and production scheduling. Its OTIF performance stands at 80%, and during peak demand periods such as December, the company fails to fulfill up to 31,159 boxes, generating monthly losses exceeding S/ 94,100. This scenario is consistent with the findings of Gómez and Vargas (2021) and Chiarini (2020), who argue that the absence of formal planning models leads to stockouts, rework, and low productivity in demand-driven manufacturing systems.

Despite the extensive literature on MPS, MRP, and advanced planning techniques in food manufacturing, a knowledge gap persists regarding their integrated application in medium-sized, multiproduct Peruvian companies, where empirical and reactive processes still prevail. There is no local evidence evaluating, through quantitative models and discrete-event simulation, the impact of integrating forecasting, MPS, and MRP on key performance indicators such as OTIF and stockouts. This gap motivated the present study, which aims to demonstrate how a formal planning architecture can effectively replace the currently used intuitive approach.

In this regard, the objective of this research is to design, implement, and validate an integrated planning system based on the Master Production Schedule (MPS) and Material Requirements Planning (MRP) to synchronize demand, materials, and capacity in a Peruvian infusion production plant. The research question guiding this study is: To what extent does the integration of forecasting, MPS, and MRP improve service level (OTIF) and reduce stockouts in a multiproduct food manufacturing environment? The article is structured as follows: first, the literature review is presented; then, the methodology and pilot test; followed by the results and statistical validation; and finally, the conclusions and recommendations.

1.1 Objectives

- To increase the service level in a herbal infusion company through an integrated production and supply planning model based on MPS and MRP, synchronizing demand with production capacity and material availability to ensure complete and on-time deliveries.
- To implement a Material Requirements Planning (MRP) model to ensure the timely availability of raw materials by defining inventory policies, safety stock levels, and lead times aligned with the MPS, thereby reducing stockouts and strengthening the procurement and supply process.
- To design a Master Production Schedule (MPS) that optimizes the weekly scheduling of orders, resources, and installed capacity, reducing downtime due to changeovers and improving productivity (boxes per labor-hour).
- To implement an integrated MPS–MRP model to synchronize supply and demand, reduce stockouts, and increase the service level ($OTIF \geq 95\%$) in the company under study.

2. Literature Review

The reviewed literature allows existing contributions to be grouped into four typologies related to production planning: forecasting methods, MPS design, MRP parameterization, and MPS–MRP integration. In the first typology, Nurprihatin (2021) and Syberg (2025) highlight that exponential smoothing models are effective tools for anticipating demand in environments with moderate variability, provided that historical data are properly cleaned and seasonal or exogenous factors are considered. These studies agree that forecasting is no longer an isolated statistical exercise but rather a strategic input that conditions system stability, establishing a direct link with the second typology.

Indeed, Cañas (2022) and Pekárciková et al. (2025a) show that the quality of the Master Production Schedule depends on forecast reliability. Their findings demonstrate that a structured MPS, particularly when products are grouped into families and time fences are applied, reduces workload variability, lowers intermediate inventories, and improves capacity utilization. A clear relationship exists between these typologies: a robust forecast enables the development of a stable MPS, while a stable MPS minimizes the need for subsequent adjustments that could compromise material availability.

The third typology addresses MRP performance and its sensitivity to MPS quality. Studies such as Seiringer et al. (2025) indicate that proper MRP parameterization—including consistent bills of materials, realistic lead times, and appropriate safety stock levels—contributes to reducing stockouts and backorder costs. Furthermore, the authors show that MRP performs more effectively when operating with updated forecasts within a rolling horizon planning

environment, allowing the production system to better respond to demand uncertainty. Overall, these findings reinforce the interdependence among the three previous typologies.

The fourth typology, focused on hierarchical MPS–MRP integration, synthesizes prior findings. Millán et al. (2023) demonstrate that the formal alignment between both planning levels can achieve service level improvements exceeding 90%, along with a significant reduction in operational variability. Literature related to APICS frameworks also agrees that such integration facilitates alignment between demand, procurement, and production, promoting greater consistency in decision-making.

Despite these advances, the four typologies reveal a relevant gap: there are no studies that analyze the integrated application of forecasting, MPS, and MRP in multiproduct companies within the Peruvian food sector, nor validations using discrete-event simulation to measure their impact on indicators such as OTIF and stockouts. This lack of empirical evidence justifies the need for applied studies that evaluate the synchronization of these tools in real-world environments. In this regard, recent literature highlights that integration across planning, procurement, and production is key to improving the efficiency and resilience of production systems (Queiroz et al. 2022), supporting the approach proposed in this research.

3. Methods

The methodology is grounded in a gap identified in the literature: the lack of studies analyzing the integrated application of forecasting, the Master Production Schedule (MPS), and Material Requirements Planning (MRP) in multiproduct companies within the food sector, as well as the absence of simulation-based validations that measure their impact on service level indicators. To address this gap, the study proposes a planning model designed to replace the empirical approach currently used by the company (Figure 1- Figure 5).

The main contribution consists of an integrated architecture based on two core components: a weekly MPS that organizes production according to forecasted demand, portfolio segmentation, and available capacity; and an MRP system parameterized with cleaned bills of materials and realistic lead times. As a key input, a forecasting system based on ETS models developed in RStudio is incorporated to identify demand patterns and quantify uncertainty. The integration of these components enables the synchronization of demand, capacity, and inventory, resulting in a more stable and predictable production flow, in line with recent approaches to integrated planning in multiproduct manufacturing systems (Zhang et al. 2022).

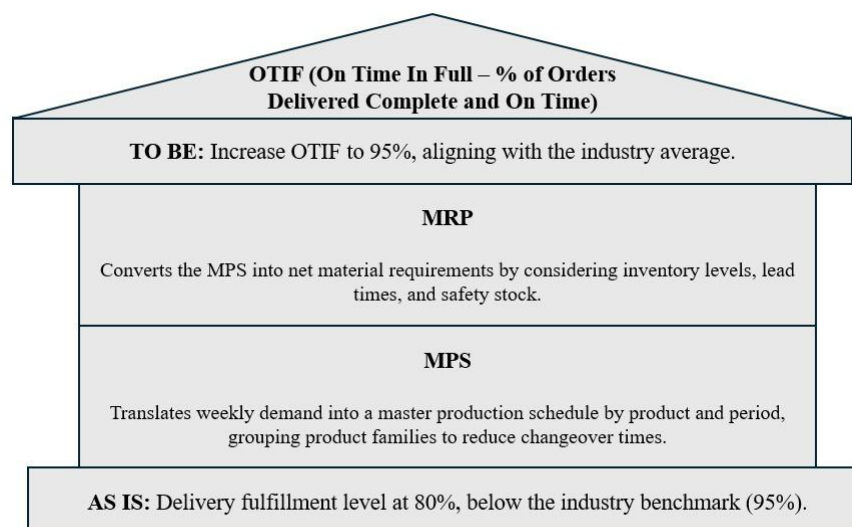


Figure 1. Macro model diagram

The integration of the model begins with the analysis of historical demand and the generation of SKU-level forecasts using ETS models, employing the upper bound of the 95% confidence interval as a preventive input. Subsequently, products are grouped into families to construct a weekly MPS that defines production quantities and time periods based on minimum lot sizes, priorities, and available capacity. Feasibility is validated through Rough-Cut Capacity Planning (RCCP). Based on the validated MPS, requirements are translated into material needs using the bill of materials (BOM), generating the MRP, which determines purchase orders and feeds back into the plan when supply constraints arise. A Gantt chart is developed to detail the sequence of activities required for implementation, including data preparation, system configuration, capacity validation, and the pilot phase. This schedule provides a clear visualization of the estimated duration, task dependencies, and key milestones, facilitating a structured implementation aligned with the company's objectives.

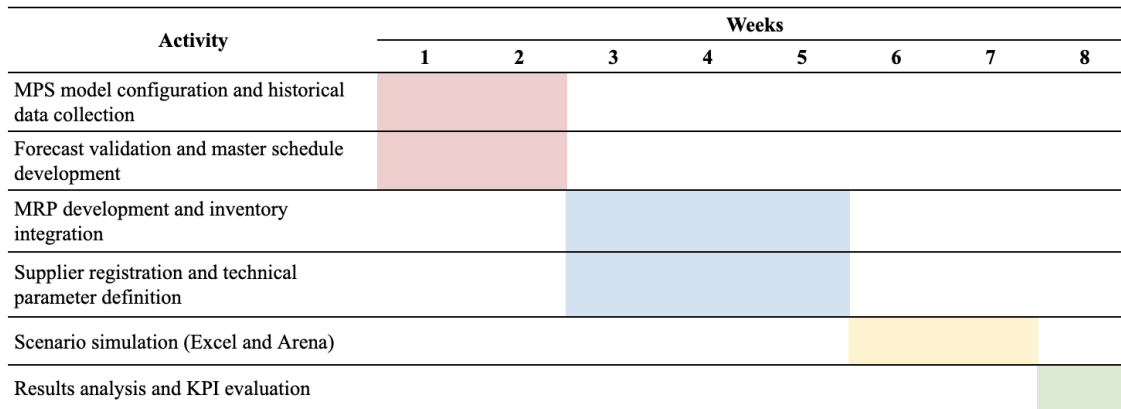


Figure 2. Gantt chart of implementation activities

The study population consisted of the total number of units sold by the infusion company during 2024 (1,066,823 boxes), selected because it reflects the overall behavior of the production and supply system, including seasonal variations and fulfillment issues. From this population, a sample of 73 boxes was determined using the finite population formula, ensuring a 95% confidence level and a 5% margin of error. A simple random sampling method was applied, given the homogeneity of the production processes, which minimizes bias and ensures representativeness.

Regarding model validity, the selected indicators represent key dimensions of operational performance. The OTIF service level is a widely used metric to assess reliability and fulfillment in the supply chain, as it integrates both timeliness and completeness of deliveries (Tian et al. 2024; Bahiyyah & Nisah 2022). Stockouts, on the other hand, reflect failures in the synchronization between demand, procurement, and replenishment, making them a critical indicator of material planning effectiveness (Arani et al. 2021). Finally, labor productivity allows the evaluation of efficiency in the use of production resources and its impact on overall system performance (Dolgui et al., 2022). Together, these indicators provide a comprehensive assessment of the impact of the proposed model in terms of service level and operational efficiency.

The aforementioned indicators were compared between the baseline scenario and the proposed scenario using Arena's Output Analyzer, applying independent confidence intervals to determine the statistical significance of the observed improvements. Table 1 presents a dashboard summarizing the percentage improvements in these indicators.

Table 1. Results dashboard

Indicator	Baseline Model (As-Is)	Improved Model (To-Be)	Improvement (%)	Interpretation
OTIF (service level)	81%	94%	16%	Significant increase in on-time and in-full deliveries.
Productivity (boxes/labor-hour)	44.2	50.3	14%	Improved operational efficiency due to reduced idle time and better workload
Stockouts (occurrences)	8,6	2,8	-67%	Significant reduction in inventory shortages due to MRP-based planning.
Procurement plan compliance	73%	93%	27%	Improved coordination between procurement and production.

4. Data Collection

For this research, a Peruvian company dedicated to the production of herbal infusions was analyzed, with the objective of characterizing the actual behavior of the production process to support the simulation model and validate the MPS–MRP proposal. Data collection was carried out through plant visits, direct observation, and time measurements of operational activities, obtaining the processing times associated with each stage of the production flow.

The recorded times correspond to ten observations per activity, allowing for the estimation of their behavior and variability. Table 2 presents the values measured on-site for each operation in the process, including activities such as order reception, raw material availability verification, box assembly, packaging, quality control, and dispatch.

Subsequently, the data were processed using Arena’s Input Analyzer software to determine the statistical distributions that best represent the behavior of each activity. These distributions were used to model both the current scenario and the proposed scenario. Table 3 presents the resulting distributions and their corresponding expressions.

Table 2. Statistical distributions by activity

Activity	Distribution	Expression
1. Order reception	Lognormal	$0.87 + \text{LOGN}(0.172, 0.158)$
2. Check raw material availability	Triangular	$\text{TRIA}(13.1, 15.1, 16)$
3. Material selection for the order	Beta	$9.79 + 1.21 \times \text{BETA}(0.525, 0.857)$
3a. Raw material request (if unavailable)	Beta	$9.07 + 1.45 \times \text{BETA}(1.41, 1.2)$
3b. Late raw material reception (if applicable)	Beta	$2.70\text{e}+03 + 269 \times \text{BETA}(0.439, 0.477)$
4. Transfer to packaging area	Beta	$1.38\text{e}+03 + 112 \times \text{BETA}(0.502, 0.593)$
5. Box assembly	Beta	$0.19 + 0.12 \times \text{BETA}(0.526, 0.652)$
6. Filling (FFS)	Exponential	$0.29 + \text{EXPO}(0.016)$
7. Packing	Beta	$0.19 + 0.12 \times \text{BETA}(2.1, 0.632)$
8. Wrapping	Beta	$0.19 + 0.12 \times \text{BETA}(0.508, 0.798)$
9. Bagging	Beta	$0.19 + 0.12 \times \text{BETA}(0.508, 0.798)$
10. Quality control	Beta	$-0.001 + 1.22 \times \text{BETA}(0.537, 0.422)$
11. Transfer to finished goods warehouse	Uniform	$\text{UNIF}(343, 382)$
12. Order consolidation	Normal	$\text{NORM}(4.99, 0.301)$
13. Order dispatch	Beta	$4.43 + 0.84 \times \text{BETA}(1.4, 1.48)$

5. Results and Discussion

When comparing the obtained results with findings reported in the literature, it is observed that they are consistent with those presented by Nurprihatin (2021), confirming that exponential smoothing models improve the alignment between production and demand. In this study, forecast stability was a key factor in effectively supporting the MPS, which is particularly relevant for SMEs in emerging markets, where demand variability and analytical limitations are common.

Regarding the MPS, the findings are consistent with Pekárciková et al. (2025b), showing improvements in capacity utilization and a reduction in rescheduling. This can be explained by the aggregation of products into families and the weekly structuring of the plan, conditions that reduce operational complexity and facilitate implementation in multiproduct environments.

Similarly, improvements in material availability and the reduction of stockouts associated with MRP are explained by proper system parameterization, particularly the cleansing of the BOM, the adjustment of lead times, and the inclusion of safety stock, in line with recent literature. These conditions are critical and highly transferable to Latin American SMEs, where supply issues are often linked to deficiencies in planning practices.

Finally, the increase in OTIF confirms that the integration of MPS and MRP leads to significant improvements in service level (Millán et al. 2023). The main contribution lies in the synchronization between production and procurement, reducing misalignments and improving overall performance. In this sense, the proposed model shows strong potential for extrapolation to multiproduct industries in emerging markets, provided that key conditions such as data quality, planning discipline, and proper parameterization are ensured.

5.1 Numerical Results

The study yielded the results presented in Table 3.

Table 3. Comparison between baseline and improved scenarios

Indicator	Baseline Model (As-Is)	Improved Model (To-Be)	Improvement (%)
OTIF (service level)	81%	94%	16%
Productivity (boxes/labor-hour)	44.2	50.3	14%
Stockouts (occurrences)	8.6	2.8	-67%
Procurement plan compliance	93%	± 4%	95%

5.2 Graphical Results

In the proposed scenario (post-improvement), the planning system exhibits a more stable and synchronized structure, with a significant reduction in disruptions caused by stockouts and unplanned rescheduling. The integration between the MPS and MRP enables the operational flow to proceed with lower variability and a more consistent sequence of tasks compared to the baseline scenario.

Additional time generated by changeovers and weekly adjustments decreases due to the development of an MPS with time fences, which reduces the dispersion and fluctuations observed in the pre-test. Likewise, proper MRP parameterization reduces the frequency of urgent replenishments and eliminates the need to reschedule orders due to material shortages, demonstrating improvements in inventory management and the continuous replenishment of critical materials. This behavior is consistent with the findings of Huarcaya-Meléndez and Platero-Mamani (2023), who highlight that even moderate variations in material availability can have a significant impact on process flow.

The simulated scenario therefore represents a more organized system with greater standardization of the production flow, where the elimination of unplanned activities and the reduction of non-value-added operations directly contribute to an increase in service level. The corresponding figure illustrates the behavior of the improved model and the optimized structure of the production process.

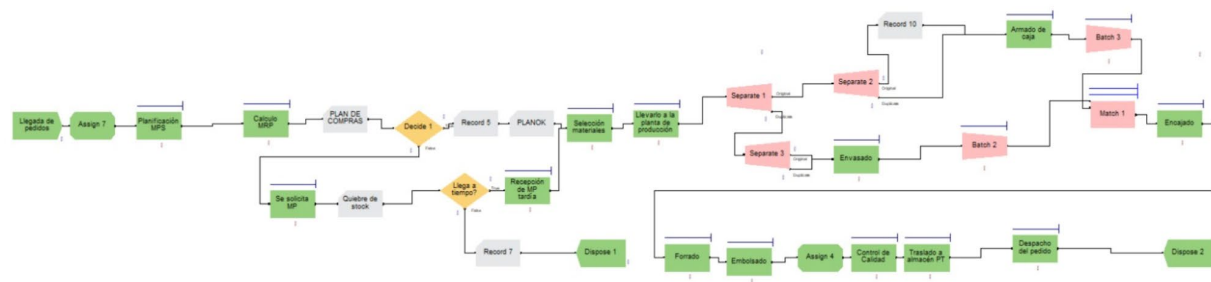


Figure 3. Arena Model

The results obtained using the Output Analyzer software for the two most relevant indicators of the study are presented below, highlighting the improvement of the proposed scenario compared to the baseline scenario.

The first indicator corresponds to the service level (OTIF), whose behavior shows a significant increase. In the current scenario, OTIF intervals ranged approximately between 78% and 83%, whereas in the improved scenario they shift to a higher range between 94% and 97%. This improvement is mainly attributed to the reduction of stockouts and the increased stability of the MPS, which enables orders to be fulfilled on time and in the required quantities.

The second indicator corresponds to stockouts, whose behavior shows a marked decrease. In the baseline scenario, the estimated confidence interval ranged between 7.8 and 9.2 stockouts per cycle, while in the proposed scenario the values decrease to a range between 2.4 and 3.1 stockouts. This reduction is directly related to the proper parameterization of the MRP, as well as improvements in the accuracy of the bill of materials and lead times, which allow for more stable inventory levels without increasing costs.

Since the independent confidence intervals obtained do not overlap, it can be concluded that the differences between both scenarios are statistically significant. The results are shown in Table 4 below.

Table 4. Confidence intervals

Indicator	Average	Std. Dev.	95% CI Lower	95% CI Upper
OTIF (%)	0.94	12	0.94	0.97
Stockouts (occurrences)	2.8	0.25	2.4	3.1
Productivity (boxes/hh)	50.3	1.1	49.8	50.8
Procurement compliance	0.93	0.04	0.91	0.95

5.3 Proposed Improvements

The proposed approach considers the implementation of a reliable forecasting model, a structured weekly MPS, and a properly parameterized MRP to improve production continuity in the infusion plant. To achieve this, exponential smoothing was used as an input for the MPS, and a simulation model developed in Arena was applied to validate the operational impact of the integrated planning approach.

The improvements implemented in scheduling times and material availability had a positive effect on the model's key performance indicators. In particular, OTIF and the frequency of stockouts show substantial operational improvement. OTIF increased due to reduced rescheduling and greater material availability, while stockouts decreased significantly as a result of BOM cleansing and the realistic configuration of lead times within the MRP.

The total time that orders remain within the system also decreased. This result is explained by the greater stability of the MPS, which limits unnecessary changes in the production sequence, and by continuous replenishment that prevents interruptions associated with material shortages. At the same time, the system's capacity to meet weekly demand increased, as the occurrence of stoppages and delays was reduced.

Improvements in process organization, reduced variability, and timely replenishment of materials contribute to a significant reduction in operational times, as noted by Ahmad (2018). This is reflected in the improved performance of key indicators, with OTIF exceeding 90%, representing a relevant improvement compared to the baseline scenario.

Finally, the analysis of operational effort before and after the improvement shows a clear reduction. This decrease is driven by fewer interruptions, reduced rescheduling, and the elimination of idle time. Achieving the same production volume with lower effort indicates a direct increase in system efficiency, in line with operations management principles.

5.4 Validation

For the pilot test, 2024 sales data from four SKUs belonging to a product family in the 20-unit presentation were used. Based on these data, a monthly forecast per SKU was developed using RStudio, given its support for time series analysis and ETS models. The process included data import and cleaning, standardization of dates and products, and demand aggregation on a monthly basis. Subsequently, the time series was structured using the *tsibble* package, completing missing periods to avoid interruptions in the modeling process.

An ETS model was fitted for each SKU, with NAIVE alternatives selected only when historical data did not allow for a valid estimation. The forecasting horizon was set to six months, generating both point forecasts and confidence intervals at 80% and 95%. For the pilot test, the upper bound of the 95% confidence interval (UB95) was adopted,

following the conservative approach recommended by Hyndman and Athanasopoulos (2021), in order to reduce the risk of stockouts and support OTIF compliance.

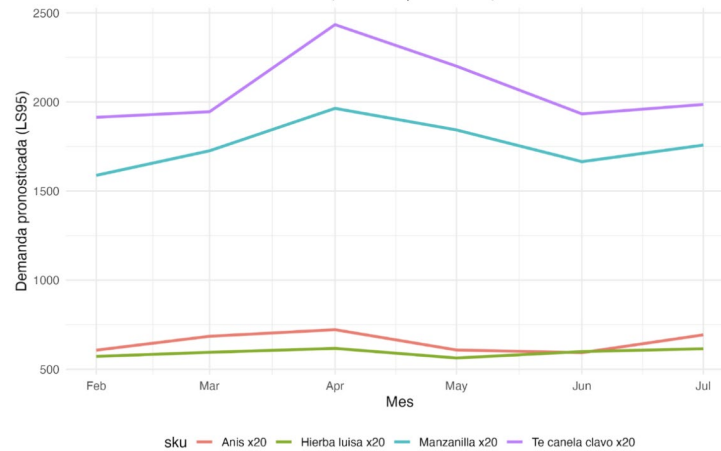


Figure 4. Monthly demand forecast

The forecasted demand for the first month was disaggregated at a weekly level to develop the Master Production Schedule (MPS), considering available capacity, family-based sequencing, and material arrivals. This MPS was then translated into material requirements through the bill of materials (BOM), generating the corresponding MRP. This integration enabled the validation of actual material availability and replenishment lead times.

In addition, a Rough-Cut Capacity Planning (RCCP) validation was performed to confirm the operational feasibility of the MPS before executing the MRP. This step allowed for the identification of potential capacity overloads and the adjustment of production volumes or sequences when necessary. The bidirectional interaction between MPS and MRP ensured consistency between production and procurement, reducing the risk of stockouts and contributing to improvements in service level (OTIF).

Overall, the pilot test validated an integrated planning workflow supported by data and quantitative models, in contrast to the empirical approach previously used by the company.



Figure 5. Pilot test procedure

6. Conclusion

- The integration of MPS and MRP transformed an empirical planning process into a structured system, achieving a service level improvement of OTIF $\geq 95\%$ compared to initial non-compliance levels of 20%. The objectives of increasing service level, reducing stockouts, optimizing productivity, and validating an integrated MPS–MRP model were successfully achieved. These results confirm the relevance of synchronizing demand, procurement, and production in Make-to-Order environments (Tobón-Valencia et al. 2022) and demonstrate the impact of their integrated implementation in an SME within an emerging market.
- The partial automation of planning increased productivity (13.6%) and employee satisfaction (11%), validating the relationship between digitalization and labor sustainability. This finding supports the approach proposed by Mejía and Martínez (2023) and extends it by demonstrating its applicability in a real small-scale manufacturing environment.
- The reduction of stockouts and rework shows that production efficiency generates operational, financial, and social benefits. This study extends the literature on hierarchical planning by integrating technical and social indicators in SMEs within emerging economies, offering a more comprehensive approach compared to studies focused solely on operational performance.
- The implementation demonstrated that data-driven planning is feasible in environments with high product diversity without requiring infrastructure investment, expanding the applicability of the MPS–MRP approach in resource-constrained contexts.
- As a practical recommendation, manufacturing SMEs are encouraged to gradually implement MPS–MRP systems supported by reliable forecasting and discrete-event simulation, prioritizing the cleansing of bills of materials and workforce training. As future research directions, it is proposed to incorporate machine learning-based forecasting models, evaluate the impact of lead time variability within MRP, and validate the model in other multiproduct industries to assess its scalability and generalization.

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