Application of Lean Service to Improve Order Fulfillment Rate in a Food Distribution Company Through Heijunka and QR-Based Poka-Yoke

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Abstract

The food distribution sector operates under high inventory turnover and requires accurate order fulfillment to maintain customer satisfaction and operational efficiency. However, many small and medium-sized distribution companies continue to experience frequent picking errors associated with product misidentification, incorrect expiration-date verification, and manual workload overload. The company analyzed in this study reported an initial Order Fulfillment Rate (OFR) of 93.2%, below the operational benchmark expected in high-rotation logistics environments [1]. To address these issues, this research proposes an integrated Lean Service model composed of two complementary phases. First, Heijunka was implemented to balance operator workload and reduce operational variability. Second, a QR-based Poka-Yoke system was introduced to automate product verification and prevent picking errors [2][3]. The proposed model was validated through Arena Simulation using operational data and pilot-test measurements collected from the warehouse environment. Simulation results demonstrated significant operational improvements. The OFR increased from 93.2% to 97.1%, while identification and counting errors decreased by 2.13 PP and 1.70 PP, respectively. These findings confirm that integrating Lean Service practices with low-cost digital verification technologies can improve picking accuracy, process stability, and operational reliability in food distribution environments [4][5].

1 Introduction

The food distribution sector operates under high inventory turnover and strict order accuracy requirements. In this context, maintaining a high Order Fulfilment Rate (OFR) is essential to ensure customer satisfaction and operational reliability. Previous studies indicate that OFR values in distribution environments commonly range between 85% and 98%, depending on process stability and warehouse control systems [1]. However, many small and medium-sized companies continue to experience operational problems associated with manual picking activities, product misidentification, expiration-date verification errors, and workload variability [2].

The company analysed in this study reported an initial OFR of 93.2%, mainly affected by operational failures during the picking process. An internal analysis showed that 56.96% of the detected errors corresponded to incorrect expiration-date verification, 28.71% to product misidentification, and 14.33% to manual counting overload. These issues demonstrate how human error and process instability negatively affect warehouse efficiency and order accuracy [3]. Lean Service methodologies have increasingly been implemented in logistics operations to reduce non-value-added activities and improve workflow stability [4].

Among the most widely used Lean tools, Heijunka contributes to balancing operational demand and reducing workload variability, while Poka-Yoke systems prevent repetitive human errors through automatic verification mechanisms [5]. Additionally, QR-based technologies have demonstrated positive results in reducing identification errors and improving traceability within warehouse operations [6]. Despite the increasing adoption of digital tools, most previous studies analyse Heijunka and Poka-Yoke independently, particularly in manufacturing environments, while limited research has evaluated their integrated application within food distribution systems supported by simulation and pilot experimentation [7].

Therefore, this research proposes an integrated Lean Service model combining Heijunka-based workload levelling and QR-based Poka-Yoke verification to improve OFR performance in a food distribution company. The proposal seeks to reduce operational variability, minimise human error, and improve process reliability through a low-cost and scalable solution [5]. The model was validated using Arena Simulation and pilot-test measurements collected under real warehouse operating conditions [6].

The main objective of this study is to improve the OFR through the implementation of Lean Service tools supported by digital verification technologies. Specifically, the research aims to identify the main operational causes affecting order

fulfilment, design an integrated improvement model, validate the proposal through simulation, and evaluate its operational impact [7]. The remainder of the paper is organised as follows: Section 2 presents the methodology and simulation model; Section 3 describes the implementation results and comparative analysis between AS-IS and TO-BE scenarios; finally, Section 4 summarises the conclusions and future research opportunities.

2 Methodology

The dependent variable in this study was the Order Fulfilment Rate (OFR), defined as the percentage of orders completed correctly without identification, expiration-date, or counting errors. The independent variables corresponded to the implementation of a QR-based Poka-Yoke verification system and the application of Heijunka workload levelling during the picking process [7].

The analysed company operates within the food distribution sector under high inventory turnover conditions. The population consisted of 28,295 historical orders, from which a representative sample of 100 orders was calculated using the finite population sampling method proposed by Cochran [8]. Additionally, a pilot test involving 92 orders was conducted to replicate the average daily operational workload.

Data collection was performed through direct observation, operational checklists, and video recording. Picking times and operational errors were registered throughout the warehouse workflow using a binary evaluation scale. Previous studies indicate that monitoring picking activities and operational times provides reliable indicators for warehouse performance assessment [9].

The research methodology consisted of four stages. First, the main operational causes affecting OFR performance were identified through process analysis [4]. Second, an integrated Lean Service proposal combining Heijunka and QR-based Poka-Yoke verification was developed [5][7]. Third, AS-IS and TO-BE models were created using Arena Simulation software [10]. Finally, the proposed model was validated using pilot-test measurements collected under real operating conditions [6].

In the AS-IS scenario, operators manually verified products and expiration dates during the picking process, generating workload imbalance and operational variability. In the TO-BE scenario, QR-based verification was incorporated to automatically validate products, while Heijunka was applied to balance high-rotation product allocation among operators according to ABC classification principles [10].

Both scenarios were evaluated using 30 independent simulation replications in Arena Simulation. The AS-IS model used historical operational data, whereas the TO-BE model incorporated pilot measurements, scanning times, and updated operational distributions [10].

3 Results

The experimental phase was conducted through a pilot study in the warehouse picking area following the methodological approaches proposed by previous logistics and Lean implementation studies [7][11]. A total of 92 orders, corresponding to the average daily operational workload, were processed under controlled conditions to evaluate operational times and picking error rates before and after the implementation of the proposed Lean Service model.

3.1 QR-based Poka-Yoke

The QR verification system validated each product in real time by scanning its code and comparing it against the order currently assigned to the operator. Based on this verification, the scanner provided immediate visual feedback, alerting the operator whether the selected item was correct and prompting them to pick the correct product when a mismatch occurred. This mechanism helped reduce picking errors by ensuring alignment between the operator's active order and the physical product being selected [7]. During the pilot, the QR-based Poka-Yoke prototype composed of an Arduino con-troller, QR reader, and LED indicators replaced the manual verification process fol-lowing the digital error-prevention principles proposed by [7].

(a) Product verification during picking

(b) Picking operation under workload balancing

Figure 1. Integrated Lean Service implementation during the pilot phase: (a) product verification process and (b) picking operation under workload balancing.

Figure 1 illustrates the practical implementation of the proposed Lean Service model within the warehouse environment. The pilot phase incorporated product verification activities and workload balancing strategies to reduce operational variability and improve picking accuracy [5][7].

3.2 Heijunka Workload Levelling

The workload levelling strategy was applied to high-rotation products identified through ABC classification. Products with higher picking frequency were redistributed among operators to reduce operational imbalance and avoid workload concentration during peak demand periods [10] [13].

Example of a high-turnover products order after the application of Heijunka-based workload levelling.

Table 1 Example of workload redistribution after Heijunka implementation.

Code	Product	Quantity	Products per Operator (5 Operators)
84448	Ropa Color Dem. Sapolio (3) 765ml	78	15-16
31415	Ropa Color Sapolio Bot. (1) 800ml	95	19
84166	Ropa Color Sapolio Bot. (2) 1800ml	83	16-17
79521	Salsa Huancaína Alicena Dpq (24) 25gr	74	14-15
81769	Salsa Ketchup Alicena Dpq (24) 25gr	91	18-19
7759	Salsa Mayonesa Alicena Dpq (24) 25gr	87	17-18
42474	Salsa Mayonesa Alicena Dpq (4) 100gr	99	19-20

The redistribution process allowed a more balanced allocation of high-turnover products among warehouse operators, reducing process variability and improving workflow continuity during picking operations [3] [10].

3.3 Arena simulation results

The AS-IS and TO-BE scenarios were evaluated using Arena Simulation based on operational data collected before and after implementation. The AS-IS model incorporated historical warehouse data, while the TO-BE model included pilot measurements, scanning times, corrected error probabilities, and the Heijunka-balanced configuration [10].. The simulation model was validated by comparing observed and simulated operational results, obtaining differences below 5%, confirming the reliability of the model for performance evaluation [10].

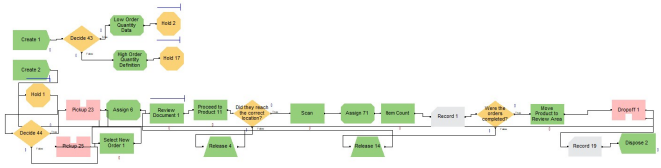

Figure 2. TO-BE picking process model developed in Arena Simulation.

The simulation outputs demonstrated a significant improvement in warehouse performance after the implementation of the integrated Lean Service model

3.4 Operational performance improvement

The TO-BE scenario achieved important improvements in operational indicators compared with the AS-IS model. The OFR increased from 93.2% to 97.1%, while identification and counting errors were significantly reduced through the implementation of QR-based validation and workload balancing mechanisms [7].

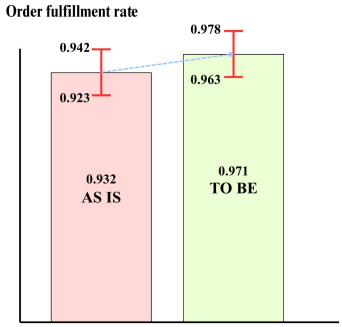

Figure 3. Comparison of Order Fulfillment Rate (OFR) between the AS-IS and TO-BE scenarios.

The TO-BE scenario achieved significant improvements in operational accuracy indicators compared with the AS-IS model. Identification errors decreased from 4.20% to 2.07% (–2.13 percentage points), while counting errors were reduced from 2.57% to 0.87% (–1.70 percentage points), reflecting the effectiveness of the proposed improvements in reducing operational mistakes and enhancing process reliability.

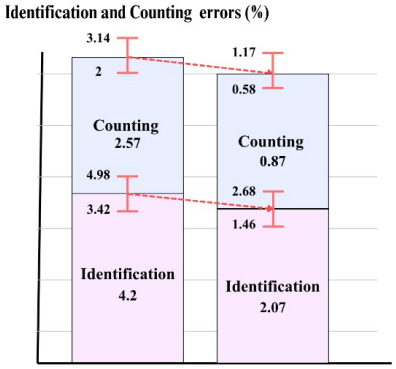

Figure 4. Comparison of identification and counting errors between the AS-IS and TO-BE scenarios.

The results indicate that the proposed Lean Service model reduced operational variability and improved picking accuracy within the warehouse environment. The integration of automatic verification and workload levelling contributed to improving process reliability and reducing repetitive human errors [3][5].

3.5 Performance comparison

Table 2. Performance comparison between the AS-IS and TO-BE scenarios.

Indicator	AS IS	TO BE	Variation
Order Fulfillment Rate (OFR)	93.2%	97.1%	+3.9 pp
Identification errors (%)	4.20%	2.07%	–2.13 pp
Counting errors (%)	2.57%	0.87%	–1.70 pp

The simulation results showed an increase of 3.9 percentage points in OFR performance. Additionally, identification errors decreased by 2.13 percentage points while counting errors were reduced by 1.70 percentage points. These findings confirm the effectiveness of combining Lean Service principles with low-cost digital verification systems in high-rotation food distribution environments [4][7].

4 Conclusion

The results obtained from the Arena Simulation and pilot implementation confirmed that the integrated Lean Service model significantly improved warehouse operational performance. The implementation of QR-based Poka-Yoke verification and Heijunka workload levelling increased the Order Fulfilment Rate (OFR) from 93.2% to 97.1%, while identification and counting errors were reduced by 2.13 pp and 1.70 pp, respectively [7]. The proposed model demonstrated that combining digital verification technologies with Lean Service principles contributes to reducing operational variability, improving picking accuracy, and increasing process reliability within high-rotation food distribution environments [3][5]. Furthermore, the implementation required low-cost technological resources, making the proposal feasible for small and medium-sized distribution companies [6]. The simulation-based validation also confirmed the effectiveness of integrating operational data with pilot measurements to evaluate warehouse performance improvements before large-scale implementation [10]. These findings are consistent with previous studies highlighting the benefits of workload balancing and error-proofing systems in logistics operations [2][7]. However, the study was conducted under controlled operational conditions and within a single warehouse environment, which may limit the generalisation of the results to companies with different operational characteristics. Future research could evaluate the long-term implementation of the proposed model and compare its performance with other digital picking technologies in larger distribution systems.

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