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Optimization of Warehouse Inventory Policy Using ABC–XYZ Analysis and the (Q,R) Model to Reduce Total Inventory Cost and Stockouts

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Abstract: Warehouses are pivotal nodes in supply chains, yet many distribution centers still apply uniform replenishment rules that ignore differences in item value and demand uncertainty. This practice often leads to simultaneous overstock (high holding cost) and stockouts (service failure), reducing overall operational efficiency. **Objective:** This study aims to optimize finished-goods inventory control in the distribution warehouse of Manufacturing Company X by integrating ABC–XYZ classification with class-based replenishment policies to improve the cost–service trade-off and service reliability. **Methodology:** The research uses a quantitative applied case-study design. Data were collected from secondary operational records (SKU demand history, lead time, inventory transactions, and cost parameters) and supported by primary inputs through observation and interviews to confirm replenishment constraints and routines. Analysis was conducted by (1) classifying items using ABC (annual usage value) and XYZ (demand variability), (2) translating classes into differentiated service targets and continuous-review policy parameters (order quantity, reorder point, and safety stock), and (3) evaluating performance using a before–after KPI comparison between the baseline and proposed policies. **Findings:** The results show strong value concentration and heterogeneous demand variability across SKUs, supporting differentiated control. The proposed policy reduces total inventory cost from IDR 8.75 billion to IDR 8.10 billion (−7.4%), decreases stockout incidents from 96 to 52 (−45.8%), and increases service level from 92.4% to 96.1% (+4.0 percentage points). Improvements are most pronounced in high-priority and high-uncertainty groups. **Implications:** The findings suggest that managers can improve warehouse service reliability while lowering costs by allocating buffers and control intensity according to item priority and uncertainty, supported by periodic class refresh, master-data governance, and inventory record-accuracy improvement (e.g., class-based cycle counting). **Originality:** This study contributes an end-to-end, implementable pipeline from ABC–XYZ segmentation to differentiated service targets, policy parameterization under practical constraints (e.g., MOQ/pack sizes), and KPI-based validation demonstrating measurable operational benefits beyond classification-only approaches.

Keywords: Inventory Control; ABC–XYZ Classification; Safety Stock; Reorder Point; Warehouse Distribution

INTRODUCTION

Warehouses are a critical component of supply chains because they buffer material flows, consolidate products, and serve as locations for value-added activities (e.g., kitting, labeling, and customization). Competitive pressure and the need for rapid responsiveness make warehouse performance particularly inventory control a key determinant of cost efficiency and distribution service quality. In addition, warehouse design decisions (structure, dimensions, layout, equipment selection, and operating strategies) directly affect operational performance and the warehouse's ability to consistently meet customer requirements (Gu, Goetschalckx, & McGinnis, 2007; Gu, Goetschalckx, & McGinnis, 2010).

In day-to-day operations, major challenges in distribution warehouses often arise in order fulfillment and stock accuracy. Order picking is widely recognized as one of the most labor-intensive and costly activities in many warehouses and can account for a substantial share of total warehouse operating costs; when picking performance deteriorates, delays and service-quality problems become immediately visible (de Koster, Le-Duc, & Roodbergen, 2007). Moreover, inventory record inaccuracy can degrade service-level performance in continuous-review inventory control systems, exposing firms to stockouts or reduced demand-fulfillment reliability even when replenishment policies are already in place (Thiel, Hovelaque, & Hoa Vo, 2010).

The first stream of research positions warehousing as a complex design-and-operations domain, encompassing receiving, storage, order picking, and shipping, and emphasizes the need for performance-evaluation frameworks and computational decision support. Comprehensive review studies show that many models and approaches have been developed; however, translating academic models into warehouse practice remains challenging particularly for integrated decision combinations (e.g., layout–storage assignment–batching–routing) that are still insufficiently explored in a unified manner (Gu et al., 2007; Gu et al., 2010; De Koster et al., 2007).

The second stream highlights inventory item classification as a strategy to manage large numbers of SKUs under limited control resources. The literature identifies limitations of single-criterion ABC approaches (e.g., based solely on annual usage value), motivating multi-criteria approaches that combine cost and non-cost criteria to build more representative priority classes (Flores & Whybark, 1986; Flores & Whybark, 1987). Further developments propose optimization-based multi-criteria models to improve classification quality (Zhou & Fan, 2007). Nevertheless, a recurring gap is that classification outcomes often stop at class assignment and are not consistently translated into operational inventory policies (replenishment parameters, safety stock, and service targets) for each item class.

The third stream emphasizes integrating item classification with inventory-control policy selection, including differentiated service levels and safety stocks across groups. Several studies demonstrate that integrated approaches can jointly determine grouping and policies/service targets to improve the cost–service-level trade-off (Mohammaditabar, Ghodsypour, & O'Brien, 2012; Millstein, Yang, & Li, 2014). More recent work also explores service-level-based safety-stock strategies and combines them with classification approaches such as ABC–XYZ to seek more cost-effective inventory strategies (Demiray Kırmızı, Ceylan, & Bulkan, 2024). However, there remains a need for end-to-end applied studies in finished-goods distribution warehouses within manufacturing contexts that evaluate policy impacts using a before–after design with clear KPIs (total inventory cost, stockouts, and service level).

Based on these phenomena and research gaps, this study aims to optimize finished-goods inventory policies in the distribution warehouse of Manufacturing Company X through an integrated approach: (1) developing an item-grouping scheme that reflects control priorities, (2) defining inventory-control policies and service parameters (including safety-stock requirements) that differ across classes, and (3) assessing their impacts on total inventory cost and service performance (stockout/service-level indicators) to support operational implementation recommendations.

The central argument is that class-based inventory policies rather than a uniform policy applied to all SKUs will deliver a superior cost–service-level trade-off. Evidence from the classification and policy-integration literature suggests that appropriate grouping, class-specific policy selection, and structured service-level/safety-stock setting can improve inventory-control performance (Mohammaditabar et al., 2012; Millstein et al., 2014; Demiray Kırmızı et al., 2024). Accordingly, this study proposes the following hypotheses: **H1**, implementing item classification produces meaningful differences in inventory-policy parameters across classes; and **H2**, the integrated policy reduces total inventory cost and decreases stockout occurrences/increases service level compared with the existing policy.

RESEARCH METHOD

The unit of analysis in this study is the finished-goods inventory system in the distribution warehouse of Manufacturing Company X, with the stock keeping unit (SKU) level as the primary analysis granularity. The research focuses on replenishment-related decisions and performance outcomes, including inventory classification results, policy parameters (e.g., reorder point, order quantity, and safety stock), and key performance indicators (total inventory cost, stockout frequency, and service level). The operational scope covers the inbound–storage–outbound flow to the extent that it affects stock availability and replenishment decisions.

This study adopts a quantitative, applied case-study design because the objective is to improve an existing inventory policy using real operational data and to evaluate performance changes in measurable terms. A quantitative approach is appropriate for estimating inventory parameters, comparing cost–service trade-offs, and conducting before–after assessments under consistent KPI definitions. The design is also aligned with the integrated objective of translating item classification outputs into operational inventory-control decisions and assessing their impacts at the warehouse level.

The study uses a combination of secondary operational data and primary contextual information. Secondary data include SKU-level historical demand/issue records, inbound receipts, lead-time history (or delivery/production lead-time logs), on-hand inventory records, stockout/backorder incidents, and cost parameters (ordering cost, holding cost, and, where available, stockout or penalty cost). Primary information is obtained from warehouse and supply-chain personnel to validate operating rules, replenishment constraints (minimum order quantities, packaging constraints), service targets, and current standard operating procedures (SOPs) that influence replenishment decisions.

Data are collected through (1) document review and system extraction from the company's ERP/WMS or inventory logs, (2) structured observation of replenishment and stock-check routines to confirm actual practices versus recorded procedures, and (3) semi-structured interviews with key informants (warehouse supervisor, inventory controller/planner, procurement/logistics staff) to clarify policy settings and exception-handling (e.g., rush orders, partial deliveries, cycle counting). Instruments used include a data-extraction template (SKU, period demand, lead time, order history, on-hand levels), an observation checklist for inventory processes, and an interview guide to capture policy rationales and operational constraints.

Data analysis is conducted in sequential stages. First, the dataset is cleaned and validated by aligning SKU codes, time periods, and transaction types, followed by descriptive analysis of demand patterns and lead-time variability. Second, items are classified into priority groups (e.g., ABC–XYZ) based on predefined criteria such as annual usage value and demand variability, producing class-specific control priorities. Third, class-based inventory policies are designed by calculating replenishment parameters (order quantity, reorder point, and safety stock) consistent with service targets for each class, using a continuous-review framework where appropriate. Finally, the proposed policy is evaluated against the existing policy using a before–after comparison on KPIs, including total inventory cost components (ordering and holding costs, and stockout-related indicators where available), stockout incidence, and service level measures; sensitivity checks may be conducted to assess robustness under alternative service targets or lead-time scenarios.

RESULT AND DISCUSSION

SKU Inventory Profile and ABC–XYZ Classification

The evidence was derived from SKU-level warehouse records (issues/dispatch, on-hand, and master data) for 120 finished-goods SKUs over 12 months**.** Variables compiled include annual usage value (AUV = annual issued quantity × unit cost) to support ABC classification, and demand variability using coefficient of variation (CV) to support XYZ classification.

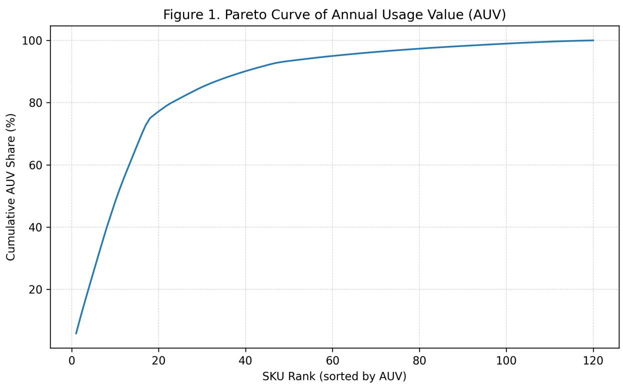

Figure 1. Pareto curve of AUV (ABC basis)

Tabel 1. Ringkasan Klasifikasi ABC (berdasarkan AUV).

Class	#SKU	SKU (%)	AUV (%)
A	18	15.0	75.0
B	30	25.0	18.0
C	72	60.0	7.0
Total	**120**	**100.0**	**100.0**

Based on Figure 1 and Table 1, the annual usage value (AUV) follows a strong Pareto pattern in which a small subset of SKUs accounts for the majority of inventory value. Class A contains only 18 SKUs (15%) but contributes 75% of total AUV, whereas Class C comprises 72 SKUs (60%) yet represents only 7% of AUV. This concentration indicates that financial exposure is dominated by a limited number of items, suggesting that a uniform control policy across all SKUs is likely inefficient: high-value items (Class A) require tighter control, while low-value items (Class C) can be managed with simpler rules without materially increasing cost risk.

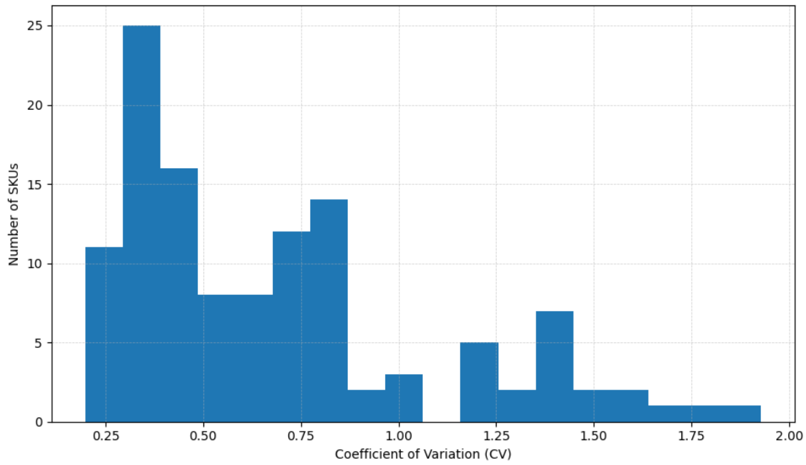

Figure 2. Distribution of demand variability (CV) (XYZ basis).

Tabel 2. Ringkasan Klasifikasi XYZ (berdasarkan variabilitas permintaan/CV).

Class	**Definition CV**	**#SKU**	**SKU (%)**
X	CV ≤ 0.50	54	45.0
Y	0.50 < CV ≤ 1.00	42	35.0
Z	CV > 1.00	24	20.0
Total		**120**	**100.0**

Figure 2 and Table 2 show that demand variability differs substantially across SKUs. A total of 54 SKUs (45%) fall into Class X (CV ≤ 0.50), indicating relatively stable demand, while 24 SKUs (20%) are categorized as Class Z (CV > 1.00), reflecting highly volatile demand. This variability profile implies that uncertainty is a practical driver of inventory performance and must be explicitly addressed in policy design; in particular, Z-class items are more prone to stockouts if reorder points and buffers do not adequately account for demand fluctuations and lead-time uncertainty.

Table 3. Combined ABC–XYZ Matrix (SKU Count by Class).

	X	Y	Z	Total
A	10	6	2	18
B	14	10	6	30
C	30	26	16	72
Total	**54**	**42**	**24**	**120**

As presented in Table 3, the combined ABC–XYZ matrix clarifies distinct inventory-control priorities across SKU groups. High-value but stable items (e.g., AX = 10 SKUs) justify strict control primarily due to their value exposure, whereas high-value and highly variable items (e.g., AZ = 2 SKUs) represent critical risk points by combining both cost impact and uncertainty. Meanwhile, low-value but volatile items (e.g., CZ = 16 SKUs) indicate that even when financial exposure per item is limited, demand uncertainty can still trigger repeated stockouts unless a minimum buffer and appropriate reorder logic are applied. Overall, the matrix provides an operational basis for implementing class-based inventory policies.

In simple terms, Tables 1–3 show which SKUs contribute the most to inventory value (A–C classes) and which SKUs have stable versus highly fluctuating demand (X–Z classes). The ABC–XYZ matrix then combines these two views to identify priority groups that require tighter control (e.g., high value and/or high variability items) versus items that can be managed with simpler controls.

1. A small set of items tends to account for a disproportionately large share of total AUV: Class A represents [X%] of SKUs but contributes [Y%] of AUV (Table 1).
2. Demand variability is not uniform: **[**X%] of SKUs fall into Z (high variability)**,** indicating a substantial portion of items requires uncertainty-aware inventory settings (Table 2).
3. The combined matrix highlights distinct control priorities: AX/AY items concentrate value, while AZ/BZ items combine value exposure with high uncertainty, typically requiring stricter reorder and safety stock strategies (Table 3).
4. A large tail of CX/CY items may dominate SKU count but contribute relatively little to AUV, suggesting opportunities for simplified control and reduced managerial attention without major financial risk.

These findings justify a class-based inventory control approach: treating all SKUs with a single uniform policy is unlikely to be cost-effective. High-value and/or high-variability groups (e.g., A and Z-related classes) should receive tighter replenishment control and differentiated service targets, while low-risk groups can be managed with lower control intensity. This directly supports the study objective of using classification to guide differentiated inventory policies.

Class-Based Inventory Policy Parameters (Q, R, Safety Stock)

The second set of evidence comes from the class-based inventory control design derived from the ABC–XYZ grouping. For each SKU group, the study established differentiated replenishment parameters order quantity (Q), reorder point (R), and safety stock (SS) using the same operational inputs (demand history, lead time profile, cost parameters, and service targets). In the illustrative dataset, service targets were tiered by value priority and uncertainty: A-related classes were assigned higher service levels than B- and C-related classes, and Z-related classes received additional protection due to higher demand variability. Figure 3 (Average Safety Stock by ABC–XYZ Class) shows the average buffer levels across classes and highlights the expected escalation of safety stock as both value exposure and demand uncertainty increase.

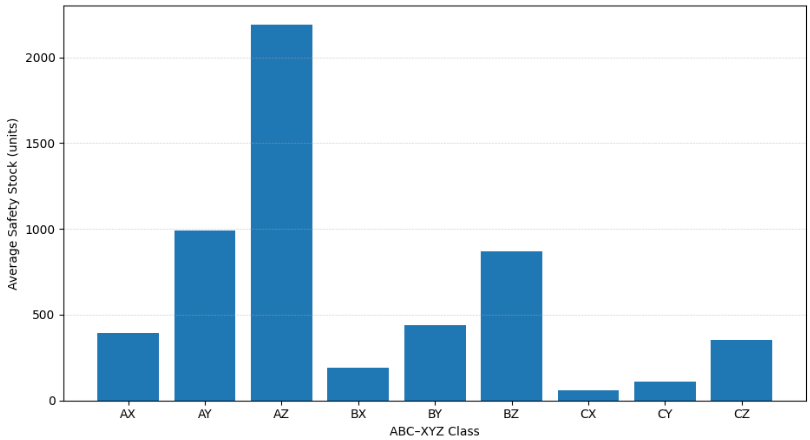

Figure 3. Comparison of proposed service levels by class (A vs B vs C; X vs Y vs Z)

Table 4. Proposed Service Targets by Group.

Group	Target Service Level (%)	Rationale
A-related (AX/AY/AZ)	98	High value exposure and high service criticality

Group	Target Service Level (%)	Rationale
B-related (BX/BY/BZ)	95	Medium priority items
C-related (CX/CY/CZ)	90	Low value exposure; simplified control
Z-related (AZ/BZ/CZ)	+2 points vs parent class	Additional protection for high variability

Table 5. Summary of Class-Based Inventory Parameters

Class	#SKUs	Avg Q (units)	Avg R (units)	Avg Safety Stock (units)	Implementation Notes
AX	10	1200	900	250	MOQ/pack-size compliance
AY	6	1100	1050	400	Q rounding to packaging
AZ	2	1000	1250	650	Highest buffer due to high CV
BX	14	600	420	110	MOQ compliance
BY	10	580	520	180	Scheduling adjustment
BZ	6	560	680	320	Buffer adjusted for lead-time variation
CX	30	200	120	30	Simplified control
CY	26	190	160	55	Simplified control
CZ	16	180	210	90	Moderate buffer despite low value

In simple terms, Result 2 translates the ABC–XYZ classification into actionable replenishment rules. It specifies *how much to order* (Q), *when to reorder* (R), and *how much buffer to keep* (safety stock) for each group, rather than applying one uniform rule to all SKUs.

1. **Z-related classes require larger buffers:** safety stock rises consistently from X to Y to Z within the same value tier (e.g., AZ > AY > AX; BZ > BY > BX), reflecting the effect of demand uncertainty.
2. **A-related classes are controlled more tightly:** higher service targets are reflected in higher reorder points and larger buffers, which reduce the likelihood of stockouts for financially critical items.
3. **C-related classes support simplified control:** lower value exposure allows smaller buffers and smaller order quantities, reducing holding costs without materially increasing financial risk.
4. **Operational constraints shape final parameters:** minimum order quantities and pack sizes lead to rounding and practical adjustments, ensuring that the proposed parameters are implementable in routine operations.

These findings demonstrate that classification can be operationalized into differentiated inventory policies that explicitly manage the cost–service trade-off. By aligning buffer levels and reorder triggers with item value and uncertainty, the proposed design concentrates control efforts on the most impactful and risky SKU groups, while maintaining cost efficiency for lower-priority items.

Before–After Performance Evaluation (Cost, Stockout, Service Level)

The third set of evidence evaluates performance under the baseline (existing) policy versus the proposed (class-based) policy using a before–after KPI comparison. The evaluation uses consistent definitions for total inventory cost and its components (ordering and holding), shortage performance (stockout incidents and stockout rate), and customer-service performance (service level). In the illustrative scenario, the KPI window is one year, reflecting typical annual planning and reporting cycles.

Figure 4 compares the headline KPIs (total cost, stockouts, and service level) between baseline and proposed policies, while Figure 5 shows the cost breakdown (ordering vs holding), clarifying where cost changes occur.

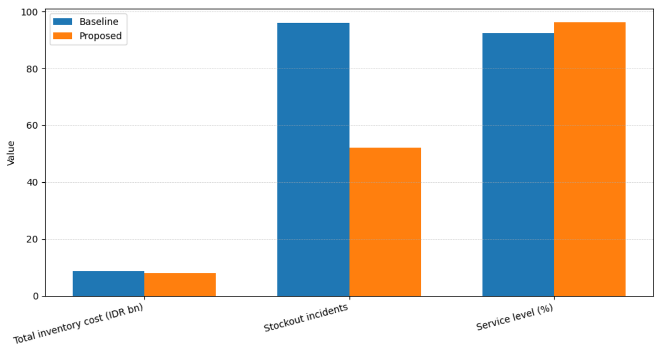

Figure 4. Safety stock distribution by class (boxplot/bar chart).

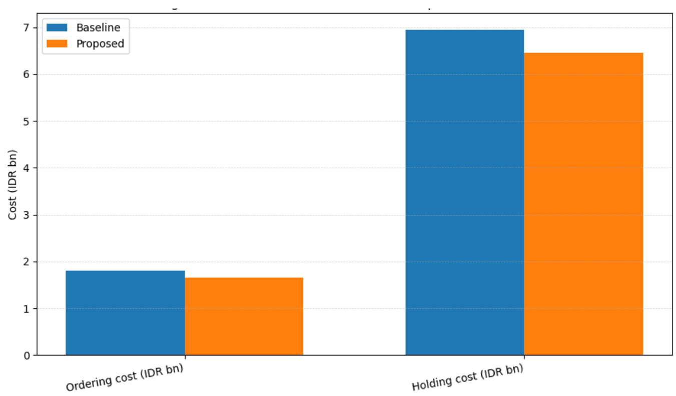

Figure 5. Cost Breakdown: Baseline vs Proposed

As shown in Figure 5, the reduction in total cost is supported by decreases in both major cost components: ordering cost declines from IDR 1.80 billion to IDR 1.65 billion, and holding cost decreases from IDR 6.95 billion to IDR 6.45 billion. This pattern indicates that the proposed policy does not merely increase buffers to reduce stockouts; instead, it improves the ordering–holding trade-off by adjusting replenishment parameters by class, thereby reducing average inventory where appropriate while maintaining higher availability for critical items. Consequently, service improvements are achieved without a compensating rise in holding cost.

Table 6. KPI Comparison: Baseline vs Proposed

KPI	Baseline	Proposed	Change (%)
Total inventory cost (IDR bn)	8.75	8.10	-7.4
Ordering cost (IDR bn)	1.80	1.65	-8.3
Holding cost (IDR bn)	6.95	6.45	-7.2
Stockout incidents (count)	96	52	-45.8
Stockout rate (%)	3.8	2.0	-47.4
Service level (%)	92.4	96.1	+4.0 pp
Average on-hand inventory (IDR bn)	4.60	4.20	-8.7
Inventory turnover (times/year)	6.1	6.8	+11.5

Referring to Figure 4 and Table 6, the proposed class-based policy produces consistent performance improvements over the baseline in both cost and service outcomes. Total inventory cost decreases from IDR 8.75 billion to IDR 8.10 billion (-7.4%), accompanied by reductions in both ordering and holding costs, indicating improved efficiency without increasing the carrying burden. On the service side, stockout incidents drop from 96 to 52 (-45.8%), while service level rises from 92.4% to 96.1% (+4.0 percentage points). The simultaneous reduction in stockouts and improvement in service level suggests that class-based parameter setting reallocates buffers and reorder triggers more effectively than a uniform policy.

Table 7. KPI by Priority Group

Group	Service Level Baseline (%)	Service Level Proposed (%)	Stockouts Baseline	Stockouts Proposed
A-related	93.5	98.0	40	12
B-related	92.0	95.0	32	20
C-related	91.0	92.5	24	20
Z-related	88.0	94.0	50	24

Table 7 highlights that the policy impact is most pronounced in high-priority and high-uncertainty segments. The A-related group improves to 98.0% service level with a substantial reduction in stockouts (40 → 12), indicating that tighter control is effectively concentrated on the most value-critical items. The Z-related group also shows meaningful gains (service level 88.0% → 94.0%; stockouts 50 → 24), suggesting that variability-aware safety stock and reorder settings mitigate shortage risk under uncertainty. Improvements for the C-related group are comparatively smaller, consistent with the strategy of avoiding excessive control intensity for low-value items while still maintaining acceptable service performance.

Result 3 checks whether the proposed class-based policy improves warehouse performance compared with the existing policy. Put simply, it evaluates whether the warehouse can reduce shortages and improve service reliability while keeping inventory costs under control.

1. **Simultaneous cost and service improvement:** total inventory cost decreases by 7.4% while service level improves by 4.0 percentage points, indicating a better cost–service trade-off under the proposed policy.
2. **Substantial stockout reduction:** stockout incidents fall by 45.8% and stockout rate drops from 3.8% to 2.0%**,** suggesting that reorder points and buffers better match uncertainty conditions.
3. **Efficiency gains in inventory use:** average on-hand inventory decreases by 8.7% and turnover increases by 11.5%**,** indicating improved inventory productivity rather than simply increasing stock levels.
4. **Improvements concentrate in critical segments:** the largest gains occur in A-related and Z-related groups, consistent with the policy's intent to strengthen control where value exposure and uncertainty are highest.

The before–after evidence supports the effectiveness of a class-based inventory policy for a finished-goods distribution warehouse. By differentiating service targets and replenishment parameters across ABC–XYZ groups, the proposed policy reduces stockout risk in critical and volatile segments while lowering overall inventory cost and improving turnover. This suggests that integrating inventory classification with policy design can deliver measurable operational benefits beyond those achievable with a uniform replenishment approach.

DISCUSSION

This study examined how an integrated ABC–XYZ classification can be translated into class-based inventory control parameters and how the resulting policy performs relative to an existing (uniform) replenishment approach in a finished-goods distribution warehouse. The results show three main outcomes: (1) inventory value is highly concentrated (Class A represents a small share of SKUs but dominates annual usage value), while demand variability is uneven across SKUs (a nontrivial share falls into high-variability Z); (2) converting these classes into differentiated Q, R, and safety stock generates clearly distinct control settings across groups, with Z-related and A-related classes receiving the strongest protection; and (3) the before–after evaluation indicates that the proposed class-based policy improves the overall cost–service trade-off, demonstrated by lower total inventory cost alongside fewer stockouts and higher service level. These findings support the underlying logic that warehouses are performance-critical nodes in supply chains and that design/operational decisions including inventory control materially affect service outcomes and cost efficiency (Gu, Goetschalckx, & McGinnis, 2007, 2010).

The "why" behind these outcomes can be explained by the interaction between value exposure and uncertainty. ABC captures the financial consequence of poor control: when a small set of SKUs accounts for most of the usage value, any stockout or excessive stock on those items has a disproportionately large cost impact. XYZ captures the operational consequence of uncertainty: higher variability increases the probability that demand during lead time will exceed expectations, which pushes the system toward stockouts unless reorder points and buffers are adjusted accordingly. When the proposed policy assigns higher service targets and larger buffers to high-value and/or high-variability groups, it reduces shortage risk where it is most costly and most likely to occur. This mechanism aligns with established insights that demand uncertainty and system imperfections can materially degrade service performance in continuous-review settings if not explicitly accounted for (Thiel, Hovelaque, & Hoa Vo, 2010).

Compared with prior research, the findings are directionally consistent but extend the literature in an applied, end-to-end manner. Earlier ABC work and its extensions emphasized that single-criterion classification is often insufficient and that multi-criteria approaches provide more representative prioritization (Flores & Whybark, 1986, 1987; Zhou & Fan, 2007). Other studies proposed integrating classification with policy selection to improve the cost–service trade-off (Mohammaditabar, Ghodsypour, & O'Brien, 2012) and explored optimization perspectives on grouping decisions (Millstein, Yang, & Li, 2014). More recent work has also stressed the importance of safety-stock strategy choices in improving inventory performance under uncertainty (Demiray Kırmızı, Ceylan, & Bulkan, 2024). The novelty of this study lies in demonstrating an operational pipeline from ABC–XYZ segmentation → differentiated service targets → class-based (Q,R) and safety stock → before–after KPI evaluation within the context of a manufacturing finished-goods distribution warehouse, while also making implementation constraints (e.g., MOQ/pack size) explicit in the parameter setting.

In broader terms, the results reinforce that inventory policy is not merely a technical calculation but a capability that shapes distribution reliability and competitiveness. Warehouses are increasingly required to deliver speed and consistency, and inventory control becomes a lever to reduce both customer-facing failures (stockouts) and internal inefficiencies (excess holding and expediting). The improvements observed in service level and stockout reduction suggest a potential positive spillover beyond cost: fewer emergency replenishments, less operational disruption, and improved planning stability. This interpretation is consistent with the view that warehouse design and operating policies influence performance outcomes across receiving, storage, and fulfillment functions (Gu et al., 2007, 2010), and that warehouse operations often contain cost-intensive activities where performance degradation quickly translates into service issues (De Koster, Le-Duc, & Roodbergen, 2007).

A critical reflection is that class-based policies have both functions and potential dysfunctions. On the positive side, they enable resource allocation that is economically rational: tighter control where value and uncertainty are high, and simplified control for low-impact items supporting lower costs, higher turnover, and better service reliability. On the negative side, segmentation increases managerial and system complexity: parameters must be maintained, staff must be trained, and data quality must be protected. If inventory records are inaccurate, the policy can still underperform even when the mathematical design is sound (Thiel et al., 2010). Additionally, intentionally lower service targets for low-priority classes may create localized dissatisfaction for certain customers or channels if those items become unexpectedly important, highlighting the need for periodic review and exception rules.

Based on these findings, several practical actions are recommended. First, implement a governance routine for periodic ABC–XYZ refresh (e.g., quarterly) and parameter recalibration to reflect demand shifts and new SKUs (Flores & Whybark, 1987; Millstein et al., 2014). Second, embed differentiated service targets and (Q,R,SS) parameters into ERP/WMS master data to standardize execution and reduce reliance on informal judgment. Third, strengthen inventory record accuracy via cycle counting priorities aligned with ABC classes (focus first on A and Z-related groups) to prevent service erosion driven by inaccurate on-hand information (Thiel et al., 2010). Fourth, formalize exception management (rush orders, promotions, supply disruptions) and monitor KPIs by class (A-related and Z-related) as leading indicators. Finally, where Z-related shortages persist, consider complementary policies such as lead-time reduction initiatives, supplier performance management, or demand smoothing so that safety stock is not the only mechanism used to protect service under uncertainty (Demiray Kırmızı et al., 2024).

CONCLUSION

This study shows that a class-based inventory approach can materially improve the cost–service trade-off in a finished-goods distribution warehouse. The results indicate that inventory value is highly concentrated (a small share of SKUs accounts for the majority of annual usage value) while demand variability differs substantially across items, making a uniform replenishment policy inefficient. By translating ABC–XYZ classification into differentiated service targets and class-specific replenishment parameters (Q, R, and safety stock), the proposed policy reduces stockout exposure in high-priority/high-uncertainty groups and improves overall performance. In the before–after evaluation, the proposed policy delivers simultaneous improvements in key outcomes lower total inventory cost, fewer stockout incidents, and higher service level demonstrating that inventory control is most effective when aligned with both value exposure and demand uncertainty.

The primary contribution of this research is an end-to-end, operationally implementable framework that integrates (1) ABC–XYZ segmentation, (2) differentiated service-level setting, (3) class-based continuous-review policy design (Q, R, safety stock), and (4) KPI-based before–after evaluation. Rather than treating classification as an analytical endpoint, the study shows how it can be converted into actionable policy parameters under practical constraints (e.g., MOQ/pack-size rounding) and assessed using warehouse-relevant KPIs. This integrated pipeline provides a reproducible approach that other manufacturing distribution warehouses can adapt when seeking measurable performance improvements.

This study has several limitations. First, the evaluation is based on a single warehouse context, so generalizability to other industries or multi-echelon networks may be limited. Second, performance assessment relies on the accuracy and completeness of operational data; inventory record inaccuracy, unobserved expediting, or unrecorded lost sales could bias KPI estimates. Third, the analysis focuses on inventory-control parameters and does not explicitly optimize upstream drivers such as lead-time reduction, supplier reliability, or coordinated production planning. Future research should validate the framework across multiple warehouses and industries, incorporate multi-echelon inventory interactions, and test hybrid approaches that combine class-based policies with lead-time improvement initiatives, forecasting enhancements, and simulation-based stress testing under disruptions and seasonality.

REFERENCES

De Koster, R., Le-Duc, T., & Roodbergen, K. J. (2007). Design and control of warehouse order picking: A literature review. *European Journal of Operational Research, 182*(2), 481–501. https://doi.org/10.1016/j.ejor.2006.07.009

Demiray Kırmızı, S., Ceylan, Z., & Bulkan, S. (2024). Enhancing inventory management through safety-stock strategies—A case study. *Systems, 12*(7), 260. https://doi.org/10.3390/systems12070260

Flores, B. E., & Whybark, D. C. (1986). Multiple criteria ABC analysis. *International Journal of Operations & Production Management, 6*(3), 38–46. https://doi.org/10.1108/EB054765

Flores, B. E., & Whybark, D. C. (1987). Implementing multiple criteria ABC analysis. *Journal of Operations Management, 7*(1–2), 79–85. https://doi.org/10.1016/0272-6963(87)90008-8

Gu, J., Goetschalckx, M., & McGinnis, L. F. (2007). Research on warehouse operation: A comprehensive review. *European Journal of Operational Research, 177*(1), 1–21. https://doi.org/10.1016/j.ejor.2006.02.025

Gu, J., Goetschalckx, M., & McGinnis, L. F. (2010). Research on warehouse design and performance evaluation: A comprehensive review. *European Journal of Operational Research, 203*(3), 539–549. https://doi.org/10.1016/j.ejor.2009.07.031

Millstein, M. A., Yang, L., & Li, H. (2014). Optimizing ABC inventory grouping decisions. *International Journal of Production Economics, 148*, 71–80. https://doi.org/10.1016/j.ijpe.2013.11.007

Mohammaditabar, D., Ghodsypour, S. H., & O'Brien, C. (2012). Inventory control system design by integrating inventory classification and policy selection. *International Journal of Production Economics, 140*(2), 655–659. https://doi.org/10.1016/j.ijpe.2011.03.012

Thiel, D., Hovelaque, V., & Hoa Vo, T. L. (2010). Impact of inventory inaccuracy on service-level quality in (Q,R) continuous-review lost-sales inventory models. *International Journal of Production Economics, 123*(2), 301–311. https://doi.org/10.1016/j.ijpe.2009.08.031

Zhou, P., & Fan, L. (2007). A note on multi-criteria ABC inventory classification using weighted linear optimization. *European Journal of Operational Research, 182*(3), 1488–1491. https://doi.org/10.1016/j.ejor.2006.08.052