How to cite this article: Saengphueng, S., Suwannalert, S., Nanthakij, N., & Chartniyom, S. (2026). A Multi-Echelon Inventory Management Framework for Cost Optimization in a Coffee Shop Supply Chain Using (R, s, S) Policies. *Journal of Logistics and Supply Chain Operations, 11*(3), 55-75. https://doi.org/10.53848/jlsco.v12i1.280650

Received: August 11, 2024
Revised: April 08, 2025
Accepted: December 29, 2025

A Multi-Echelon Inventory Management Framework for Cost Optimization in a Coffee Shop Supply Chain Using (R, s, S) Policies

Sompop Saengphueng[1]*, Salintip Suwannalert[2], Natthapat Nanthakij[3] and Siradej Chartniyom[4]

Abstract

The purpose of this research was to present a multi-level inventory management framework designed for a corporate structure with a single distribution center and multiple branches. The model employs a two-level inventory approach, specifically designed for handling diverse product categories, by utilizing a hybrid ordering system. At the core of this framework is a composite inventory policy, denoted as (R, s, S), which effectively manages product demand using statistical probability distributions—a critical consideration in retail operations. Additionally, the model accounts for fixed lead times associated with the transfer of products between the distribution center and its branches, ensuring timely replenishment. The framework's efficacy is demonstrated through a case study involving a large coffee shop enterprise managing 172 distinct products. The case study reveals that the proposed model not only streamlines inventory planning but also significantly reduces inventory management costs. When compared to traditional methods, the framework achieves a monthly cost reduction from 22,849.05 baht, marking a 2.32% decrease. This reduction highlights the model's potential for improving operational efficiency and cost-effectiveness across various product lines. In summary, this approach offers a robust solution for multi-level inventory management, enabling organizations to optimize their inventory processes and realize substantial cost savings.

Keywords: Multi-Echelon inventory system, Hybrid policy, (R, s, S) policy,
Coffee shop supply chain

Type of Article: Research Article

* Corresponding author
[1] Lecturer, Department of Industrial Engineering, Srinakharinwirot University, E-mail: sompops@g.swu.ac.th
[2-3] Alumni, Department of Industrial Engineering, Srinakharinwirot University, E-mail: salintipdonut@gmail.com, natthapat-nn@hotmail.com
[4] Lecturer, Department of Industrial Engineering, Srinakharinwirot University, E-mail: siradej@gmail.com

การพัฒนากรอบการจัดการสินค้าคงคลังหลายระดับแบบ (R, s, S) เพื่อเพิ่มประสิทธิภาพต้นทุนในโซ่อุปทานร้านกาแฟ

สมภพ แสงผึ้ง[1]*, สลิลทิพย์ สุวรรณเลิศ[2], ณัฐภัทร นันทกิจ[3] และ สิรเดช ชาตินิยม[4]

บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อเสนอกรอบการจัดการสินค้าคงคลังแบบหลายระดับ สำหรับองค์กรที่มีโครงสร้างประกอบด้วยศูนย์กระจายสินค้าเพียงแห่งเดียวและหลายสาขา โดยใช้แนวคิดการบริหารสินค้าคงคลังแบบสองระดับที่ออกแบบมาเพื่อรองรับหมวดหมู่ผลิตภัณฑ์ที่หลากหลายผ่านระบบการสั่งซื้อแบบผสมผสาน กรอบการทำงานนี้มีนโยบายหลักคือแบบจำลอง (R, s, S) ซึ่งช่วยจัดการความต้องการของสินค้าได้อย่างมีประสิทธิภาพผ่านการแจกแจงความน่าจะเป็นทางสถิติ อันเป็นปัจจัยสำคัญในธุรกิจค้าปลีก นอกจากนี้แบบจำลองยังพิจารณาระยะเวลาดำเนินการคงที่ระหว่างศูนย์กระจายสินค้าและสาขาต่างๆ เพื่อให้สามารถเติมสินค้าได้อย่างทันท่วงที ประสิทธิภาพของกรอบการทำงานนี้ได้รับการประเมินผ่านกรณีศึกษาร้านกาแฟขนาดใหญ่ที่มีผลิตภัณฑ์แตกต่างกันจำนวน 172 รายการ ผลการศึกษาแสดงให้เห็นว่าโมเดลที่นำเสนอสามารถเพิ่มประสิทธิภาพในการวางแผนสินค้าคงคลังและลดต้นทุนได้อย่างมีนัยสำคัญ โดยสามารถลดต้นทุนรายเดือนได้ 22,849.05 บาท หรือคิดเป็น 2.32% เมื่อเทียบกับวิธีการแบบดั้งเดิม โดยสรุป กรอบการทำงานนี้นำเสนอแนวทางที่น่าเชื่อถือและคงประสิทธิภาพในการจัดการสินค้าคงคลังแบบหลายระดับ ซึ่งช่วยให้องค์กรสามารถเพิ่มประสิทธิภาพและลดต้นทุนในกระบวนการบริหารจัดการสินค้าคงคลังได้อย่างมีประสิทธิผล

คำสำคัญ : ระบบคลังสินค้าหลายระดับ, นโยบายไฮบริด, นโยบาย (R, s, S), โซ่อุปทานร้านกาแฟ

ประเภทบทความ : บทความวิจัย

* ผู้รับผิดชอบงานหลัก

[1] อาจารย์ ภาควิชาวิศวกรรมอุตสาหการ คณะวิศวกรรมศาสตร์ มหาวิทยาลัยศรีนครินทรวิโรฒ, อีเมล: sompops@g.swu.ac.th

[2-3] บัณฑิตวิศวกรรมอุตสาหการ คณะวิศวกรรมศาสตร์ มหาวิทยาลัยศรีนครินทรวิโรฒ อีเมล: salintipdonut@gmail.com, natthapat-nn@hotmail.com

[4] อาจารย์ ภาควิชาวิศวกรรมอุตสาหการ คณะวิศวกรรมศาสตร์ มหาวิทยาลัยศรีนครินทรวิโรฒ, อีเมล: siradej@gmail.com

ผ่านการรับรองคุณภาพจากศูนย์ดัชนีการอ้างอิงวารสารไทย (TCI.) อยู่ในกลุ่ม 2 สาขามนุษยศาสตร์และสังคมศาสตร์

1. Introduction

The full-service coffee shop business is experiencing rapid expansion and significant popularity, largely driven by substantial foreign investments in Thailand. Consequently, the structure of such businesses in Thailand typically comprises a fundamental distribution network involving product importers, distribution centers, and retail outlets offering a diverse range of raw materials and coffee shop equipment.

This study reveals that the current coffee shop incurs a high monthly cost of 984,896.71 Baht due to its existing inventory management system, which based on the experience of ordering methods, resulting in inventory shortages that hindered meeting customer demand across various branches. This deficiency incurred additional costs for maintaining inventory and missed opportunities due to insufficient product availability, thereby potentially leading to customer dissatisfaction stemming from inadequate inventory planning.

Consequently, in response to these challenges, the project's developers implemented a two-level inventory management system (Multi-Product Two-Echelon Inventory System) tailored for the coffee shop service center business. This system involved one distribution center and three nearby branches, aiming to enhance inventory distribution planning across multiple product categories for improved operational efficiency.

The (R, s, S) inventory policy was chosen over other models because of its ability to address the key challenges of delayed order fulfillment and high inventory management costs. As noted by Göçken et al. (2015), this policy ensures that the reorder point provides sufficient stock until the next order arrives, while the order-up-to level determines the maximum inventory level. This dynamic helps mitigate the risk of stockouts, which was a major challenge in fulfilling orders on time. Additionally, Visentin et al. (2023) highlighted that the (R, s, S) policy offers a cost-effective balance between flexibility and control by reducing system nervousness compared to (s, S) and achieving better cost performance than (R, S). This adaptability allows businesses to adjust order placements based on demand fluctuations, ensuring inventory availability while avoiding excessive replenishments.

Furthermore, as mentioned in Visentin et al. (2021), this model relaxes the assumption that fixed replenishment costs cover both review and delivery expenses, making it a more precise and cost-efficient strategy. By implementing the (R, s, S) policy, businesses can strike a balance between maintaining service levels and minimizing inventory costs, making it an ideal solution to the identified challenges.

Additionally, the (R, s, S) policy effectively controls inventory costs by separating review and ordering expenses, as discussed in Mely Permatasari et al. (2017). This distinction makes the policy particularly useful when managing high-value or frequently used raw materials, as demonstrated in their sample calculation using MAT25. The policy also provides a more structured approach to replenishment compared to (R, S), as it only triggers orders when inventory falls below the reorder point, thereby preventing unnecessary stock accumulation.

2. Research's Objective

1. Refine inventory management practices.

2. Reduce overall costs by lowering inventory holding costs by 1-10% and minimizing unnecessary replenishment expenses.

3. Enhance branch responsiveness to customer needs.

3. Conceptual framework

In response to these challenges, the developers have implemented a two-level inventory management system which is designed for the coffee shop service center business as shown in Figure 1.

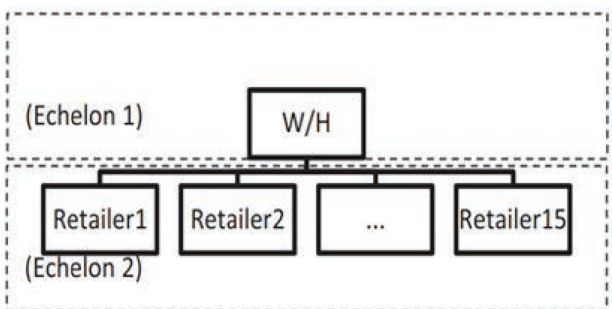

Figure 1 Two-level inventory system

Muangprom et al., (2020)

This system involved one distribution center and three nearby branches as shown in Figure 2, for improved operational efficiency.

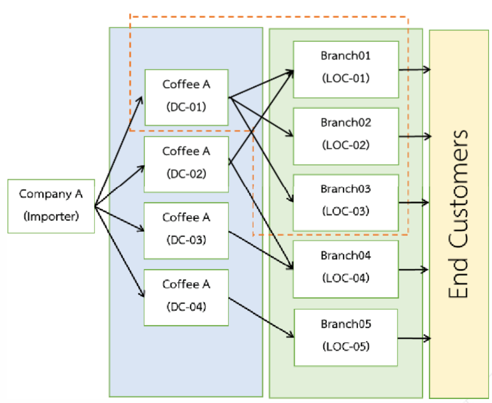

Figure 2 Framework of supply chain from the selected coffee companies (in red dot line)

4. Literature review

4.1 Two-level inventory management involves implementing a policy that governs a distribution center and N branches under unified company directives, aiming to minimize overall costs across these facilities. This approach varies based on the product types, categorized as: (1) single product type implementations, structured as a model for two-level inventory policies (Silver et al., 2016) and (2) multiple product types, implemented by using a joint replenishment strategy and developing a multi-product, multi-echelon inventory control model (Zhou et al., 2013).

Pasandideh et al. (2018) investigated a multi-product inventory policy under a vendor-managed inventory (VMI) system in a two-level supply chain comprising a single supplier and multiple retailers. They formulated the joint replenishment problem as a constrained integer nonlinear programming model and employed a teacher-learner-based optimization algorithm to solve it.

4.2 Selective inventory management is a strategic approach within management practices, involving the categorization of inventory into subgroups based on their significance, followed by the application of suitable inventory management theories designed to each subgroup. Kumar and Chakravarty (2015) conducted a study aimed at enhancing inventory management and control in a large multi-specialty tertiary care hospital of the Armed Forces through ABC–VED analysis. This approach ensures that critical and high-value items are closely monitored and effectively managed.

4.3 The two-level inventory management policy. This policy involves two distinct levels (Muangprom et al., 2020), illustrated in Figure 1: Level 1 pertains to the overall inventory held at the central warehouse, representing the aggregate inventory for the company. Level 2 focuses on inventory held at retail branches, encompassing products currently stocked and those in transit to the branches. By using this inventory policies, it can dictate the timing and quantity of goods procurement properly. The following are important policies which include:

4.4 The inventory policy (R, s, S) constitutes a composite model wherein orders are periodically reviewed at fixed intervals R (Silver et al., 2016). Inventory levels are similarly assessed during these intervals, and orders are placed when inventory falls to s units or below. Orders are then initiated to replenish stock levels up to S units.

The deployment of a two-level inventory control system entails complexity in practical applications, which is addressed through an established model utilized in this research.

4.5 The mixed ordering system involves hybrid approaches that facilitate concurrent handling of diverse inventory types. It allows for simultaneous inventory level assessments at regular intervals and determines reorder points and quantities relative to maximum inventory thresholds (Rossi, 2021). This approach involves preparation costs related to the simultaneous procurement of products. This could result in savings on transportation costs, inspection of incoming goods, and documentation expenses associated with ordering processes (Sengjan, 2014).

The study investigates a two-level inventory model designed to manage multiple product categories. This model, utilized in inventory systems where various items are centralized in a single warehouse, employs the mixed-item inventory policy (R, sj, Sj) (Visentin et al., 2021). This approach integrates both single-item procurement policies and simultaneous procurement policies, within the framework of two-level inventory management. This structure involves a central distribution center responsible for distributing products to N branches. Based on a comprehensive literature review, several significant case studies in inventory management were identified. One study examined a two-level inventory storage policy involving a central warehouse and retail outlets (Muangprom et al., 2020). A different case study concentrated on applying a two-tier inventory model made for a single product type (Sengjan, 2014). Furthermore, Wongcharoensangsiri (2018) applies a two-tier inventory model across multiple product categories, incorporating a mixed-method approach (R, s, S) for effective management. Juan and Rene (2020) conducted a survey that covered multi-level inventory management strategies, emphasizing a distribution center servicing multiple branches amidst uncertain customer demand dynamics.

4.6 Comparison of reviewed studies

A summary table that compares the reviewed studies and highlights the novelty of this research was shown in Table 1.

Table 1 Comparison of Reviewed Studies on (R, s, S) Inventory Policy

Study	Focus Area	Key Findings	Limitations	Novelty of this research
Göçken et al. (2015)	Interdependence of review period and order-up-to level	(R, s, S) ensures sufficient stock and cost efficiency	Does not address demand fluctuations or cost breakdown	Incorporates real-world cost factors and dynamic demand patterns
Visentin et al. (2023)	Cost performance and reduced system nervousness	(R, s, S) balances flexibility and stability better than (s, S) and (R, S)	Does not separate review and ordering costs	Extends the cost model by distinguishing review and ordering expenses
Visentin et al. (2021)	Separation of review and ordering costs	More precise cost allocation in (R, s, S)	Limited empirical validation	Applies the model to a real-world case study with measurable improvements

Table 1 Comparison of Reviewed Studies on (R, s, S) Inventory Policy (Cont.)

Study	Focus Area	Key Findings	Limitations	Novelty of this research
Permatasari et al. (2017)	Application of (R, s, S) to raw material inventory	Sample calculation using MAT25	Focuses on a single product type	Expands applicability to a multi-product inventory system

5. Research Methodology

5.1 Study of a two-level inventory system.

The study focuses exclusively on the supply chain of a coffee company distributing products to the DC-01 distribution center, which includes three nearby branches: LOC-01 branch, LOC-02 branch, and LOC-03 branch as can be seen from Figure 3.

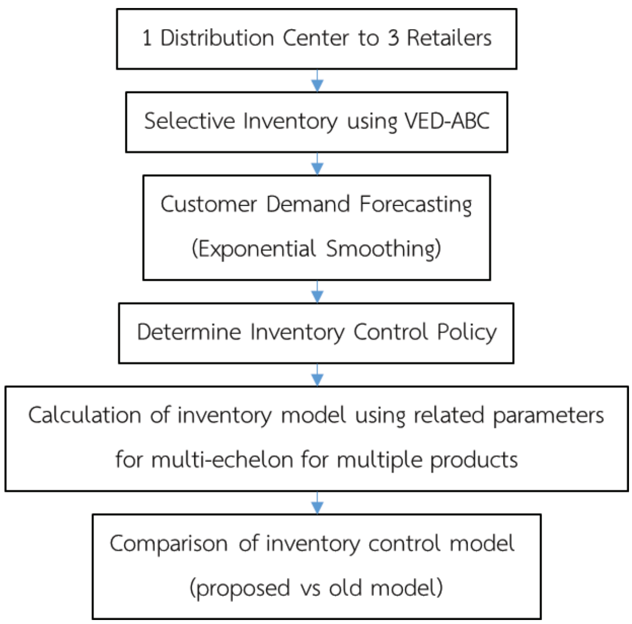

Figure 3 Flowchart for research methodology

5.2 Gathering data for the case study company

The data was collected from February 2021 to January 2022. Total products were 475 SKUs. The complexity of managing product categories within businesses stems from the inherent differences across each category, requiring proper grouping. Additionally, the valuation of warehouses, as depicted in Figure 3, involves diverse products with varying sales behaviors. As a result, conducting analysis using VED (Vital, Essential, Desirable) principles becomes crucial. The distribution center houses a total of 475 SKUs valued at 1,897,846 baht, categorized into seven distinct groups: Espresso Machine, Coffee Grinder, Blender, Fruit Concentrate & Syrup, Raw Materials, Spare Parts, and Yami.

Suggested concepts for inventory management. In this study, a hybrid ordering system incorporating an inventory policy denoted as (R, s, S) is considered. This hybrid model monitors inventory levels at regular intervals (R) and initiates orders when levels drop to or below s units, aiming to replenish inventory up to S units.

The study has also developed a two-tier inventory model designed for various product categories, providing flexibility to manage different types of inventories simultaneously. This method enables the simultaneous evaluation of inventory levels and computation of reorder points and optimal order quantities relative to maximum inventory thresholds.

5.3 Development of the model: Group-Selective inventory management.

Group-selective inventory management combines VED and ABC analyses by first performing a VED analysis and then reorganizing the results using ABC classification (Umadevi & Umamaheswari, 2023). Based on expert managerial assessment, V products were categorized as coffee shop machinery, E as coffee raw materials, and D as consumables (e.g., cups, lids, napkins, bottles, glasses). VED analysis shown in Table 2.

Table 2 VED analysis for the coffee shop

Group	# SKUs	Total product percentage	Total product’s value percentage
V	79	16.63	45.89
E	172	36.21	42.08
D	224	47.16	12.03
Total	475	100	100

This study specifically focuses on product group E due to its high significance, active nature, and they were coffee raw materials. However, relying solely on VED analysis may impact profitability, as certain products in categories E and D are high-selling items that contribute significantly to the company's profits. The product type and sales volume must be taken into consideration together, so ABC analysis was performed afterward.

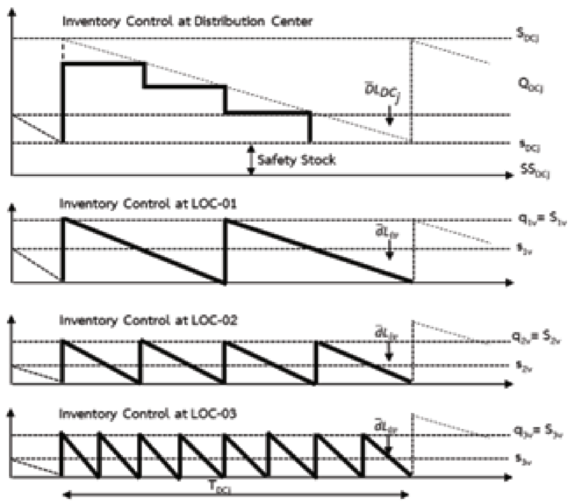

Figure 4 Two-level inventory system movement (Thaimanee & Lorchirachunkun, 2011)

5.4 Quantitative Forecast: Exponential smoothing forecast

Exponential smoothing was chosen for forecasting due to its ability to handle various components of a time series effectively, including level, trend, and seasonality. This method assigns exponentially decreasing weights to past observations, giving more significance to recent data points, making it particularly suitable for datasets where recent trends are more indicative of future values. Batselier and Vanhoucke (2017) highlighted the importance of assigning greater weight to more recent tracking periods, which exponential smoothing accomplishes efficiently.

Table 3 presents a dual-criteria analysis comparing the importance levels to business operations alongside the average monthly sales volume

		average monthly sales volume			Total
		A	B	C	
importance levels to business operations	V	17 SKUs	21 SKUs	41 SKUs	79 SKUs
	E	33 SKUs	53 SKUs	86 SKUs	172 SKUs
	D	51 SKUs	75 SKUs	98 SKUs	224 SKUs
		101 SKUs	149 SKUs	225 SKUs	475 SKUs

Additionally, Svetunkov et al. (2022) demonstrated the flexibility of the Complex Exponential Smoothing (CES) model, which encodes the observed value and error term as a complex variable, allowing for better handling of different data patterns compared to traditional methods.

Furthermore, Barrow et al. (2020) emphasized the use of robust parameter estimation techniques, such as M-estimators, which enhance the accuracy and reliability of exponential smoothing models. Udenio et al. (2022) showed that exponential smoothing models with seasonal components significantly outperform non-seasonal models under certain demand conditions, making exponential smoothing a versatile choice for various forecasting scenarios. Compared to other methods like moving average, ARIMA, and linear regression, exponential smoothing provides a balance of simplicity, efficiency, and accuracy, making it a superior choice for forecasting trend-based, non-seasonal data.

An analysis of 475 product items using four forecasting methods identified exponential smoothing as the most suitable approach due to the trend-based, non-seasonal nature of the data. This method was selected for forecasting demand across the distribution center and three branches.

$$F_t = F_{t-1} + a \cdot (A_{t-1} - F_{t-1}) \qquad (1)$$

where:

F_t is the desired forecast value for time period t,

F_{t-1} is the forecast value for the previous time period *t-1*,

a is the smoothing constant (where $0 \le a \le 1$),

A_{t-1} is the actual value in time period *t-1*,

5.5 Measuring forecast error

Various types of error measurements include Mean Absolute Deviation (MAD), Mean Squared Error (MSE), Mean Absolute Percentage Error (MAPE), and Standard Error (SE).

5.6 Setting inventory policy

In defining the details of the policy, data from product group categorization will be evaluated based on two criteria: their influence on business operations and their value. This process includes incorporating forecasted demand values to determine ordering intervals, safety stock levels, reorder points, and maximum inventory thresholds at warehouse levels.

5.7 Calculating costs associated with the system: inventory control.

Calculating inventory control costs provides a comprehensive understanding of the financial implications of managing inventory, allowing businesses to optimize their operations and remain competitive.

Table 4 displays the calculated values using the exponential smoothing method with a smoothing parameter (α) set to 0.5.

Example of forecast value for product list 395			
Month	**Demand**	**Forecast value**	**SE**
Feb	955	955	0.00
Mar	1131	1043	7744.00
Apr	1049	1046	9.00
May	1298	1172	15876.00
Jun	856	1014	24964.00
Jul	1155	1085	4970.25
Aug	1458	1271	34875.56
Sep	1340	1306	1181.64
Oct	1125	1215	8156.35
Nov	985	1100	13260.96
Dec	1253	1177	5840.30
Jan	1251	1214	1384.65
Average 12 months			9855.23

This research includes ordering and storage costs, highlighting their impact on inventory management and cost optimization (illustrated in Table 5).

5.8 Two-level inventory management for multiple product categories

A model designed for multiple product categories within a coffee company. The model is structured upon a hybrid system incorporating a mixed ordering approach, denoted by a mixed inventory policy (R, s, S) (Thaimanee & Lorchirachunkun, 2011).

Table 5 Compiles costs at distribution centers and branches

Expense type	**Expense**	
	DC	**Branches (3)**
1. Ordering costs	42 baht / time	38 baht / time
2. Storage costs	0.015 per month	0.022 per month

Given

Index (Indices)

DC = Distribution center

i = branch

j = Product types at the distribution center

v = Product type at branch

Variable

L = Lead time (set distribution center equal to branch)

Q_{DCj} = The order quantity at which the distribution center orders product type j at one time

q_{iv} = The quantity ordered at branch i for picking up product type v from the distribution center in a single transaction

s_{DCj} = Level of additional order points for category j products at the distribution center

s_{iv} = Additional order point level of product type v at branch i

S_{DCj} = Maximum inventory level of category j products at distribution centers

S_{iv} = Maximum inventory level of product type v at branch i

SS_{DCj} = Safety inventory levels of category j products at distribution centers

SS_{iv} = Safety inventory level of product type v at branch i

Parameter

K_{DCc} = Expenses for ordering basic products at the distribution center

K_{Rc} = Expenses for ordering basic products at branch i (specified to be the same for all branches)

K_{DCj} = Expenses for additional orders of category j products at the distribution center

K_{Rv} = Expenses for additional orders of product type v at branch i (set to be the same for all branches)

h_{DCj} = Expenses for storage of category j products at the distribution center

h_{iv} = Expenses for storage of product type v at branch i (specified to be the same for all branches)

C_{DCj} = Price of product category j at the distribution center

c_{iv} = Price of product type v at branch i

D_{DCj} = Demand for category j products at distribution centers

$\underline{DL_{DCJ}}$ = The average demand over an uncertain time period during which products of type j need to be ordered in advance before they are received at a distribution center.

$\underline{dL iv}$ = The average demand that occurs during the pre-order period before receipt of the product at branch i of type v.

d_{iv} = Demand for product type v at the branch

$[\alpha_{DCj}]$ = The number of time periods for ordering product type j is how many times TDC1

$[\alpha_{iv}]$ = The number of time periods for ordering product type v is how many times "t" _"i1"

$[\alpha]$ = Number of ordering periods at one distribution center and N branches

Decision variable

T_{DC_1} = Order times for the most frequently ordered types of merchandise at distribution centers

T_{DC_j} = Ordering time for category j products at the distribution center

t_{i1} = Ordering time for the most frequently ordered types of products at branch i

t_{iv} = Ordering time for product type v at branch i

R = Ordering time at one distribution center and N branches

T_1 = Lead times for the most frequently ordered product types at one distribution center and N branches.

T = Ordering time at one distribution center and N branches (specified T=R)

5.9 Calculate the ordering time period.

Ordering is the time of ordering (as shown in Table 5) and will be considered in the distribution center and various branches. Can be calculated from the following equation:

Set j to represent the product type index at the distribution center. When the order has been arranged.

$$T_{DC_1} \le T_{DC_4} \le T_{DC_3} \le \ldots \le T_{DC_N}$$

$$T_{DC_j} = \sqrt{\frac{2K_{DC_c}}{h_{DC_j} D_{DC_j}\ C_{DC_j}}} \qquad (2)$$

Therefore, to optimize ordering costs, the parameter

α_{DCj} will be rounded to an integer, representing the time interval between orders for type j products at the distribution center.

$$T_{DC_j} = \lfloor \alpha_{DC_j} \rfloor T_{DC_1} \qquad (3)$$

Set v to represent the product category index at branch i when the ordering has been completed.

$$t_{i1} \le t_{i2} \le t_{i3} \le \ldots \le t_{iN}$$

$$t_{iv} = \sqrt{\frac{2K_{Rc}}{h_{iv} d_{iv} c_{iv}}} \qquad (4)$$

Therefore, the time between orders for goods of type v at branch i can be written as

$$t_{iv} = \lfloor \alpha_{iv} \rfloor t_{i1} \qquad (5)$$

Shortest ordering time T_{DC_1} of product type j at the distribution center.

$$T_{DC_1} = \sqrt{\frac{2(K_{DC_c} + \sum_{j=1}^{N} \frac{K_{DC_j}}{\lfloor \alpha_{DC_j} \rfloor})}{(\sum_{j=1}^{N} h_{DC_j} D_{DC_j} C_{DC_j} \lfloor \alpha_{DC_j} \rfloor)}} \qquad (6)$$

Shortest ordering time t_{i1} of product type v at branch i

$$t_{i1} = \sqrt{\frac{2(K_{Rc} + \sum_{1=1}^{M} \sum_{V=1}^{N} \frac{K_{Rv}}{\lfloor \alpha_{iv} \rfloor})}{(\sum_{i=1}^{M} \sum_{V=1}^{N} h_{iv} d_{iv} c_{iv} \lfloor \alpha_{iv} \rfloor)}} \qquad (7)$$

Therefore, the shortest ordering time T_1 of two inventory levels is given.

$$T_1 = \sqrt{\frac{2(K_{DC_c} + \sum_{j=1}^{N} \frac{K_{DC_j}}{\lfloor \alpha_{DC_j} \rfloor} + K_{Rc} + \sum_{1=1}^{M} \sum_{V=1}^{N} \frac{K_{Rv}}{\lfloor \alpha_{iv} \rfloor})}{(\sum_{j=1}^{N} h_{DC_j} D_{DC_j} C_{DC_j} \lfloor \alpha_{DC_j} \rfloor) + (\sum_{i=1}^{M} \sum_{V=1}^{N} h_{iv} d_{iv} c_{iv} \lfloor \alpha_{iv} \rfloor)}} \qquad (8)$$

Therefore, the ordering time (T) at one distribution center and N branches

$$T = \lfloor \alpha \rfloor T_1 \qquad (9)$$

when $\lfloor \alpha_{DC_j} \rfloor = \lfloor \alpha_{iv} \rfloor = \lfloor \alpha \rfloor$

5.10 Calculate the point of additional orders.

It determines the point of ordering products (as shown in Table 5). When inventory reaches a predetermined level, more products will be ordered in the designated quantity.

The additional order point at the distribution center will be equal to

$$s_{DC_j} = P \times (b_{DC_j} - a_{DC_j}) + a_{DC_j} \quad (10)$$

Where s_{DC_j} = additional order point level

P = *Service level*

a_{DC_j} = *minimum demand*

b_{DC_j} = *maximum demand*

The additional order point at the branch will be equal to

$$s_{iv} = \bar{d}L_{iv} \quad (11)$$

where s_{iv} = Additional order point level at branch i

$\bar{d}L_{iv}$ = The average demand that occurs during the time the product is ordered in advance of the product being received.

5.11 Calculate the amount of safety inventory.

The quantity of products that need to be stored to prevent shortages (as shown in Table 5) due to variations in demand and lead times. The level of reserve inventory available only at the distribution center will be equal to

$$SS_{DC_j} = s_{DC_j} - \bar{D}L_{DC_j} \quad (12)$$

5.12 Calculate the quantity of products in the order

Must order Q quantity of products (as shown in Table 5) and how much must be reserved for inventory. The system will then be able to respond to product demand.

The quantity of products at the distribution center will be equal to

$$Q_{DC_j} = D_{DC_j} \lfloor \alpha_{DC_j} \rfloor T_{DC_1} \quad (13)$$

The quantity of products at the branch will be equal to

$$q_{iv} = d_{iv} \lfloor \alpha_{iv} \rfloor t_{i1} \quad (14)$$

5.13 Calculate the maximum inventory quantity.

maximum inventory quantity (as shown in Table 5) depends on the order quantity. However, to avoid inventory shortages, a specific quantity of safety stock should be maintained.

The maximum inventory level at the distribution center will be equal to

$$S_{DC_j} = SS_{DC_j} + Q_{DC_j} \quad (15)$$

The maximum inventory level at the branch will be equal to

$$S_{iv} = q_{iv} \quad (16)$$

5.14 Calculate the lowest cost in inventory management.

Consider adopting an inventory model. In order to have the lowest costs (as shown in Table 5), there is one distribution center, and a total of 3 branches as follows

Lowest cost AC^*_{DCj} of product type j at the distribution center.

$$AC^*_{DC_j} = \sqrt{2(K_{DC_c} + \sum_{j=1}^{N} \frac{K_{DC_j}}{\lfloor \alpha_{DC_j} \rceil})(\sum_{j=1}^{N} h_{DC_j} D_{DC_j} \lfloor \alpha_{DC_j} \rceil)} + \sum_{j=1}^{N} C_{DC_j} D_{DC_j} \quad (17)$$

Lowest cost AC^*_{iv} of product type v at branch

$$AC^*_{iv} = \sqrt{2(K_{Rc} + \sum_{1=1}^{M} \sum_{V=1}^{N} \frac{K_{Rv}}{\lfloor \alpha_{iv} \rceil})(\sum_{i=1}^{M} \sum_{V=1}^{N} h_{iv} d_{iv} \lfloor \alpha_{iv} \rceil)} + \sum_{i=1}^{M} \sum_{v=1}^{N} c_{iv} d_{iv} \quad (18)$$

5.15 Analyze the results of the study by comparing inventory policies

The comparison of inventory policies involves analyzing the mixed inventory policy (R, s, S) against the original inventory policy (T, S). This comparison aims to enhance the developed model of inventory management, ensuring it aligns with future business requirements and effectively meets customer needs.

Table 6 Examples of various values regarding the inventory policy in the EA product group at the distribution center and all 3 branches

Product order	Sub group	T_{DC}	DC (DC 01)				LOC-01			LOC-02			LOC-03		
			SS_{DC}	s_{DC}	Q_{DC}	S_{DC}	s_{1v}	q_{DC}	S_{1v}	S_{2v}	q_{2v}	S_{2v}	S_{3v}	S_{3v} q_{3v}	S_{3v}
395	EA	3	122	140	340	461	9	165	165	3	62	62	3	51	51
396	EA	3	47	54	134	181	4	65	65	2	44	44	2	29	29
400	EA	3	21	25	63	84	2	38	38	1	21	21	1	18	18
394	EA	3	21	24	54	75	2	27	27	1	22	22	1	20	20
398	EA	6	31	46	352	382	7	156	156	6	130	130	5	110	110

Table 7 Costs of a two-level inventory model for multiple product categories at a distribution center and a total of 3 branches

Location	Total (baht per month)
DC-01	962,047.66
LOC-01	377,991.60
LOC-02	237,523.23
LOC-03	195,764.64
	1,773,327.13

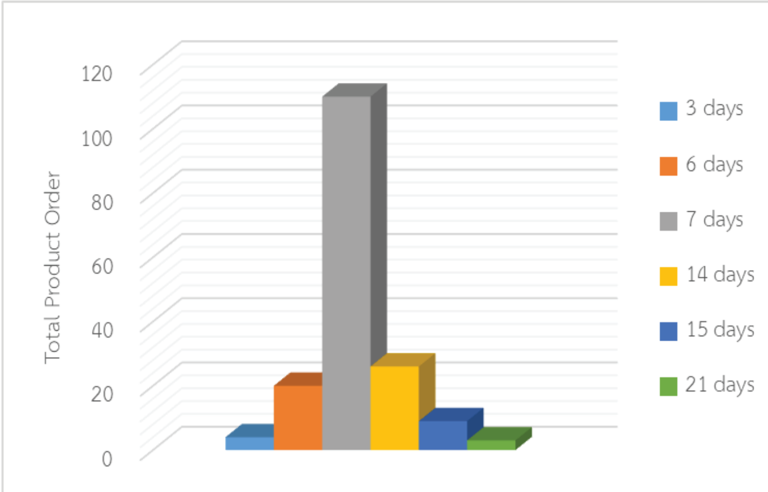

Figure 5 Number of product groups in ordering of product group E

6. Results and Discussion

6.1 Ordering time comparison

for the mixed inventory policy (R, s, S) is shorter compared to the original inventory policy (T, S). Moreover, the new policy exhibits increased frequency of orders, facilitating batch ordering of multiple items simultaneously. As illustrated in Figure 5, products can be grouped into six categories, this ultimately lowers operational costs and improves responsiveness to customer demands across different branches.

6.2 Safety inventory comparison

The analysis of product for group E at the distribution center (as depicted in Table 6) reveals that the total amount of safety inventory (SS) under the mixed inventory policy (R, s, S) exceeds that of the original inventory policy (T, S).

Increasing safety stock levels can mitigate the risk of stockouts and ensure product availability, thereby enhancing customer satisfaction and operational continuity. However, this strategy entails trade-offs, including elevated carrying costs and the immobilization of capital that could be allocated to other strategic initiatives. Achieving an optimal balance in safety stock levels is crucial for minimizing costs while effectively meeting demand. Utilizing precise forecasting methods, such as exponential smoothing, can support this balance by delivering accurate demand predictions and enabling more responsive inventory management.

6.3 Comparison of maximum inventory quantities

The analysis of product group E at the distribution center (as presented in Table 6) indicates that the maximum inventory quantity (S) under the mixed inventory policy (R, s, S) exceeds that of the original inventory policy (T, S). This reflects the structured supply chain of the new policy, which emphasizes adequate distribution to meet customer needs and serve nearby branches effectively.

6.4 Comparison of lowest costs in inventory management

The analysis of operating expenses at the distribution center for product group E reveals that the two-level inventory model for multiple product types (R, s_j, S_j) yields lower costs compared to the original policy, reducing monthly expenses by 22,849.05 baht, equivalent to 2.32% (As shown in Table 8). This outcome demonstrates the applicability of the developed model to a full-service coffee shop business, effectively lowering overall inventory management costs compared to previous methods.

Table 8 Example comparison of inventory policies in EA product groups at the distribution center and all 3 branches.

Order	Product	Sub Group	L (days)	*Old Policy*			Policy (R, s, S)		
				T_{DC}	SS_{DC}	S_{DC}	T_{DC}	SS_{DC}	S_{DC}
395	Coffee Espresso Plus Neo 500g.	EA	2	5	65	329	3	122	461
396	Coffee Espresso Blend 500g.	EA	2	10	23	201	3	47	181
400	GT-250 Mixed green tea 500g	EA	2	10	14	98	3	21	84
394	Coffee Gold Roast Neo 500g.	EA	2	10	20	92	3	21	75
398	TGM-55 Green tea 500g.	EA	2	15	41	207	6	31	382

Table 9 Comparison of lowest costs.

Group	Old Policy (Baht)	Policy (R, s, S) (Baht)	% Difference
EA	697,046	684,722	1.77%
EB	218,633	210,116	3.90%
EC	69,218	67,210	2.90%
Total	984,897	962,048	2.32%

7. Conclusion

The project implemented a two-tier inventory control system for various products within a specific company setup. This includes a central distribution center and three nearby branches: LOC-01 branch, LOC-02 branch, and LOC-03 branch. All these entities operate under a unified company policy. The project involves selecting an inventory model derived from a hybrid system incorporating a mixed ordering policy (R, s, S), tailored to the statistical demand distribution patterns of the products. Based on the comparison of the developed two-tier inventory model with previous research projects focusing on distribution centers within product group E, an analysis of four key performance indicators—ordering time, safety inventory level, maximum inventory level, and lowest inventory management cost—yielded significant insights. Firstly, the model shown a consistent ordering period, facilitating simultaneous orders for multiple product types. Secondly, it exhibited a higher ordering frequency than systems in previous studies, resulting in elevated levels of safety and maximum inventory. Thirdly, cost analysis indicated a reduction in monthly inventory management expenses by 2.32%, from 22,849.05 baht initially. These outcomes underscore the model's efficacy in guiding inventory management strategies and optimizing ordering policies to meet the specific operational needs of the coffee company.

7.1 Limitations of the Study

The study's limitations include its reliance on specific data sets and forecasting methods, which may not be generalizable to all products. Additionally, the assumption that past trends will continue may not hold true in volatile markets. Methodological constraints, such as specific parameters in exponential smoothing, could impact the robustness and accuracy of the results. External factors like economic shifts, supply chain disruptions, or changes in consumer behavior were not accounted for, which can significantly affect forecasting accuracy.

7.2 Challenges in Scaling the Model

Scaling the model to larger or more complex supply chain presents challenges such as data integration from various sources, ensuring data accuracy and consistency, and managing increased variability and uncertainty in demand forecasting. Implementing advanced technological solutions like real-time data analytics and machine learning can help, but they require substantial investment and expertise. Maintaining visibility and control over an extensive supply chain network is crucial for timely decision-making and risk mitigation.

8. Suggestion

8.1 Recommendations for implementing

Several additional considerations can be addressed. Firstly, evaluating the inventory turnover rate provides insight into how efficiently products move through the system, complementing existing performance metrics. Secondly, expanding the analysis to encompass other inventory-related expenses beyond ordering and storage costs offers a comprehensive view of total operational expenditures. These considerations collectively contribute to refining the inventory management framework, ensuring it remains agile, and cost-effective.

8.2 Recommend for future research

Future research could focus on optimizing inventory turnover rates to guide investment strategies and purchase cycles, while addressing additional costs such as transportation and stockout costs. Integrating inventory management with transportation route planning and location analysis for new branches could also be explored further. Additionally, developing flexible ordering models tailored to individual branches may enhance distribution efficiency and provide valuable insights for improving supply chain operations.

9. Acknowledgement

The researcher would like to express gratitude for the financial support provided by the Faculty of Engineering at Srinakharinwirot University.

References

Barrow, D., Kourentzes, N., Sandberg, R., & Niklewski, J. (2020). Automatic robust estimation for exponential smoothing: Perspectives from statistics and machine learning. *Expert Systems with Applications, 160*, 113637. https://doi.org/10.1016/j.eswa.2020.113637.

Batselier, J., & Vanhoucke, M. (2017). Improving project forecast accuracy by integrating earned value management with exponential smoothing and reference class forecasting. *International Journal of Project Management*, *35*(1), 28–43. https://doi.org/10.1016/j.ijproman.2016.10.003.

Göçken, M., Boru, A., Dosdoğru, A. T., & Geyik, F. (2015). (R, s, S) inventory control policy and supplier selection in a two-echelon supply chain: An Optimization via Simulation approach. *2015 Winter Simulation Conference (WSC)*, *16*(2), 241–252. https://doi.org/10.1109/wsc.2015.7408320.

Juan, P., & Rene, A. M. (2020). Multi-echelon inventory management policies: A case study for a two-echelon supply chain. *International Conference on Industrial Engineering and Operations Management*, Indiana State University, USA, 165-175.

Kumar, S., & Chakravarty, A. (2015). ABC–VED analysis of expendable medical stores at a tertiary care hospital. *Medical Journal Armed Forces India*, *71*(1), 24–27. https://doi.org/10.1016/j.mjafi.2014.07.002.

Muangprom, T., Amaratchakun , K., & Dusadeenode, S. (2020). Multi-echelon inventory policy: Case study of wine retailers. *Operations Research Network*, 271. https://logistics.nida.ac.th/wp-content/uploads/2020/02/fullpaper-multiechelon.pdf.

Pasandideh, S. H. R., Niaki, S. T. A., & Ahmadi, P. (2018). Vendor-managed inventory in the joint replenishment problem of a multi-product single-supplier multiple-retailer supply chain. *Journal of Modelling in Management*, *13*(1), 156–178. https://doi.org/10.1108/jm2-11-2016-0099.

Permatasari, P. M., Ridwan, A. Y., & Santosa, B. (2017). Inventory Policy Determination for Raw Materials in ILY Pharmaceutical using Periodic Review (R, s, S) and Periodic Review (R, S) Method to Minimize Total Inventory Cost. *MATEC Web of Conferences*, *135*, 00056. https://doi.org/10.1051/matecconf/201713500056.

Rossi, R. (2021). *Inventory Analytics. In library.oapen.org*. Open Book Publishers. https://library.oapen.org/handle/20.500.12657/49414.

Sengjan, P. (2014). *Inventory system by inventory theory: A case study of Ban Nongka Cooperative, Khon Kaen Province.* Bachelor's thesis, Faculty of Science, Khon Kaen University.

Silver, E. A., Pyke, D. F., & Thomas, D. J. (2016). *Inventory and production management in supply chains (4th ed., p. 810).* CRC Press. https://doi.org/10.1201/9781315374406.

Svetunkov, I., Kourentzes, N., & Ord, J. K. (2022). Complex exponential smoothing. *Naval Research Logistics (NRL)*, *69*(8), 1108–1123. https://doi.org/10.1002/nav.22074.

Thaimanee, H., & Lorchirachunkun, W. (2011). *Multi-product two-echelon inventory system: Deterministic demand and probabilistic lead time*. Master's thesis, National Institute of Development Administration.

Udenio, M., Vatamidou, E., & Fransoo, J. C. (2022). Exponential smoothing forecasts: taming the bullwhip effect when demand is seasonal. *International Journal of Production Research*, 1–18. https://doi.org/10.1080/00207543.2022.2048114.

Umadevi, G., & Umamaheswari, S. (2023). Advancing Healthcare Service Efficacy by Optimizing Pharmaceutical Inventory Management: Leveraging ABC, VED Analysis for Trend Demand. *International Journal of Statistics in Medical Research*, *12*, 283–293. https://doi.org/10.6000/1929-6029.2023.12.33.

Visentin, A., Prestwich, S., Rossi, R., & Tarim, S. A. (2021). Computing optimal (R,s,S) policy parameters by a hybrid of branch-and-bound and stochastic dynamic programming. *European Journal of Operational Research*, *294*(1), 91–99. https://doi.org/10.1016/j.ejor.2021.01.012.

Visentin, A., Prestwich, S., Rossi, R., & Tarim, S. A. (2023). Stochastic dynamic programming heuristic for the (R, s, S) policy parameters computation. *Computers & Operations Research*, *158*, 106289. https://doi.org/10.1016/j.cor.2023.106289.

Wongcharoensangsiri, B. (2018). Cost reduction and service level control in inventory management by periodic review system in retail business in Thailand. *Kasem Bundit Engineering Journa*l, *8*(3), 51–71. https://ph01.tci-thaijo.org/index.php/kbej/article/view/155599/119694.

Zhou, W.-Q., Chen, L., & Ge, H.-M. (2013). A multi-product multi-echelon inventory control model with joint replenishment strategy. *Applied Mathematical Modelling*, *37*(4), 2039–2050. https://doi.org/10.1016/j.apm.2012.04.054.