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RESEARCH ARTICLE

Enhancing Online Warehouse Management Efficiency with ABC-XYZ Analysis and Forecasting Techniques: A Case Study in Thailand's Automotive Accessories Sector

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ABSTRACT

This was an explanatory sequential research design with a mixed-method approach used in key business operation factors focusing on training, management support, technology integration, employee engagement, and customer satisfaction across various sectors. In this study, 138 online store operations participants were interviewed. This was followed by small group interviews with 10 key informants who had years of experience in the online management of warehouses. The study brought out the derived benefits from the integration of ABC-XYZ analysis and forecasting techniques in the attainment of operational excellence, cost reduction, and inventory fulfillment based on the market pull for the businesses in the different economic sectors.

INTRODUCTION

Thailand stands as the most important nexus of production of vehicles in ASEAN and the 10th in the world, being a catalyst for the growing accessories sector for automobiles. This would be pivotal with respect to the economic fabric of this industry and will present a huge portfolio ranging from the essential parts to aesthetic enhancements, including high-fidelity car stereos, advanced GPS systems, and vibrant decorative lights (Tansakul & Shirahada, 2016). The trajectory is in line with marking the sector as one of the main drivers of the economy, bearing in mind the automotive output and sale, which have seen an annualized growth of 8.2%. This aggregate export value reached more than 1.31 trillion baht between 2022-2023, driving a substantial contribution to Thailand's GDP. In addition to the regional ASEAN countries of Indonesia, the Philippines, and Malaysia, this industry has also had its eye on more massive international markets, especially Latin America and the Middle East (Amano, 2009).

With all this growth, digital transformation has enabled the adoption of the sales channels online to access the strategic order within the domain of auto accessories. These platforms enable extensive reach across global markets and remove the difficulty of time-zone differences while providing round-the-clock, 24/7 consumer engagement and transactional capabilities (Verhoef et al. 2022). To rise to the occasion, the paradigm shift calls for dexterous supply chain management and agile inventorying systems capable of facilitating the effortless real-time movement of consumer demands. The advent of the internet introduced a new way of selling online but also comes with its own risk, such as old stock, and increases logistic expenditure; therefore, the most valuable operational necessity that has been put forth is effective online warehouse management (Costa & Castro,2021). This case study reports a leading business within this sector, listed in the top 100 most favorites under the category of "Automotive Products" on Shopee Thailand. This firm was found to have substantially inefficient logistics, more so over the last financial year between 2021 and 2022. Some of the supportive evidence to such a noted case includes a notably increased value by 22% in the cost of warehouse management, average time of holding products that increased to 52 days, and storage costs accumulation to a percentage of 3% of the inventory valuation (Tasa LED Company, 2023). It focuses detailed scholarly discourse on different facets of online warehouse management, such as strategies and predictive modeling for the best reorder points and levels of stocks. Synthesizing ABC-XYZ with robust forecasting models, however, prevails as visible research gaps, for there are streamlining of operational efficiency in a manner so as to minimize fiscal drains that accrue due to outdated stock (yang et al., 2021).

This research is aimed at trying to bridge this gap through a review of strategies integrating ABC-XYZ analysis with focus forecasting techniques as applied in the case of an online automotive accessories business in Mahasarakham Province. This is an example of innovative models of scalable online warehouse management leading the potential community-driven benchmark for them to be followed for community-driven economic revitalization and sustainable growth. The purpose of this study is aimed at enhancing not only the logistical efficacy but also the economic resilience of the community and the larger region.

Objectives

- To investigate the correlation between training hours and employee productivity levels in manufacturing industries.
- To assess the impact of management support on job satisfaction among middle-level managers in service-oriented businesses.
- To evaluate how the integration of advanced technology in operations influences financial performance in retail businesses.
- To examine the relationship between employee engagement levels and staff turnover rates in IT companies.
- To explore the link between customer satisfaction and customer loyalty within the e-commerce sector.

LITERATURE REVIEW

Thailand stands as the most important nexus of production of vehicles in ASEAN and the 10th in the world, being a catalyst for the growing accessories sector for automobiles. This would be pivotal with respect to the economic fabric of this industry and will present a huge portfolio ranging from the essential parts to aesthetic enhancements, including high-fidelity car stereos, advanced GPS systems, and vibrant decorative lights (Preedakorn et al., 2023; Kanval et al., 2024). The trajectory is in line with marking the sector as one of the main drivers of the economy, bearing in mind the automotive output and sale, which have seen an annualized growth of 8.2%. This aggregate export value reached more than 1.31 trillion baht between 2022-2023, driving a substantial contribution to Thailand's GDP. In addition to the regional ASEAN countries of Indonesia, the Philippines, and Malaysia, this industry has also had its eye on more massive international markets, especially Latin America and the Middle East (Cerdeiro et al, 2021).

An ABC-XYZ analysis is one of the basic common techniques of inventory categorization. It includes the ABC analysis, wherein items are categorized on the basis of their importance and the respective value, along with the XYZ analysis, which categorizes the items on the basis of the variability of their demand (Keemers, 2022). In context of warehouse management, the approach of ABC analysis helps control the inventory to the optimum level, reducing holding costs and improving the service level. Partovi and Anandarajan (2002) well researched that the ABC analysis orders management attention well, while the XYZ analysis orders flexibility of the forecasting models as per demand variability for inventory balancing at optimum levels.

Application of Forecasting Techniques in Inventory Management Forecasting approaches are some of the most pertinent tools to modern inventory management, particularly for commodities like automotive accessories. For that reason, exponential smoothing, ARIMA models, ETS models, and machine-learning approaches have been applied to a number of research contexts (Hyndman & Athanasopoulos, 2018). This will enable predictive insights useful in adjusting purchasing and stocking decisions in time, hence continuing smooth operations without incidences of overstocking or stock outs.

Online Warehouse Management Systems (WMS) implies, therefore, that the online Warehouse Management Systems (WMS) need to be integrated into the supply chain for purposes of real-time data processing and inventory tracking. According to Verma and Singh (2020), modern WMS can integrate ABC-XYZ analysis and forecasting models, which result in realizing effective decision-making processes. Online WMS technologies are based on the Internet of Things (IoT) and cloud computing for convenient, scalable, and flexible management solutions.

A case study in Thailand by Ramos et al. (2020), shows how local companies apply lean inventory techniques, combined with WMS, to adjust themselves promptly in the face of fluctuations in the demand of the market. It outlines one more advantage of the relevance for the practice of using sophisticated methods of analysis and forecasting for definite industrial scopes.

Thailand as a very interesting study location in relation to the hub of Southeast Asia in terms of automotive manufacturing and export. One area that the economic policies, infrastructure, and business environment of the host nation highly affect is the logistic and supply chain strategies. Bandoophanit et al. (2023) delve into the practices of warehouse management that are under unique dynamics within the market of Thailand and aim to throw light on the general applicability of ABC-XYZ analysis and forecasting techniques within other emerging markets that have similar emergent patterns.

In fact, it is now considered quite progressive to be combining the ABC-XYZ analysis with the forecasting techniques in the warehouse management in order to pursue a more refined practice in inventory management. Such methodologies combined assist the managers not only in understanding the importance of the product but also demand variability and prediction at much higher accuracy of the future trends.

Lee and Kang (2018) bring out a fact that with an integrated approach, there is a significant betterment in the operational efficiency of online environments, where real-time data and response time play a critical role. Literature also suggests that adoption of ABC-XYZ analysis along with advanced forecasting techniques in online warehouse management can bring a significant improvement in the operational efficiencies. It is in such industries, characterized by quick product turnover and a high rate of demand variability, where the value of this approach is especially appropriate.

METHODOLOGY

The research will take a mixed methods research design approach with an explanatory sequential design, as put forth by Creswell and Clark (2018). The research is then a dualistic kind of sequential research study where a quantitative phase of the study produces data that will be used in a subsequent qualitative phase designed to explain the initial quantitative results (Figure 1).

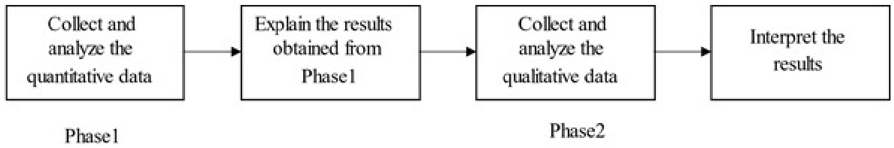

Figure 1: An explanation of the sequential design. Source: Adapted from Creswel & Clark (2018)

Phase 1: Quantitative research

Questionnaire is a quantitative data collection tool that shall be administered in order to explore factors influencing efficiency in the management of warehouses online. The target population is the online store operators in the E-Marketplace, and in light of this, the data will be collected at the individual level. A purposive sampling technique is used to select participants who are directly involved in the relevant operations. The sample size was determined from the Cohen effect size table using G-Power software while considering the effect size to be 0.15 (medium), $\alpha = 0.05$, and power = 0.95. The latter has been calculated to mean that the study will require involving 138 participants in the research (Cohen, Manion, & Morrison, 2017).

Phase 2: Qualitative research

The other phase of data collection uses the qualitative approach, targeting 10 key informants who have an experience of one year or more in online warehouse management within the business under the case study. The interviews conducted are of the small group type, employing open-ended questions. Secondary data is collected from the sales transactions of the automotive accessories through online channels from February 2022 to January 2024.

Reliability and validity

Content validity of the questionnaire was checked to be sure that it was reliable enough in collecting the data, and its consistency checked through the item analysis before it was distributed out to the respondents. The reliability of the instrument was high in the consistency during the pilot test, where 30 respondents in the pilot test had a cronbach's alpha of 0.94.

Data analysis

Profile of demographic data will be carried out on the basis of quantitative data using descriptive statistics, that is, percentages, frequencies, means, and standard deviations. The following is a one-way ANOVA, and the relationship between variables: multiple logistic regression analysis applies. This thus identifies the factors that have an effect on efficiency in inventory management from February 2022 to January 2024. The forecasting covers methods of time series analysis for the Moving Average, Single Exponential Smoothing, Double Exponential Smoothing, and Winter's Multiplicative Method in the SPSS version 28 licensed for Khon Kaen University.

Regarding the qualitative data, analysis of interviews is presented through an inductive approach in the transcript. It has been divided into topics, as are product classification, order quantities, and the best order point. The above insights are incorporated into strategies aimed at enhancing the efficiency of purchasing and warehouse management.

Ethical considerations

The same will respect ethics related to confidential participation and informed consent. All participants will be communicated in writing about the purpose of their data, voluntariness in the participation, and that the data would be treated with confidentiality.

RESULTS

Table 1: Personal factors associated with the efficiency of online warehouse management

	B	*SE*	Beta	*t*	sig
Constant	6.682	0.465		14.381	<0.001**
Age (X_1)	-0.014	0.054	-0.021	-0.253	0.801
Educational level (X_2)	0.492	0.162	0.254	3.041	0.003*
Average monthly income (X_3)	0.715	0.134	0.404	5.346	<0.001**
R = 0.51	R^2 =0.26	Adjusted R^2 =0.24	SEE= 0.58		

From Table 1, an equation representing how personal factors relate to the efficiency of warehouse management is Efficiency = 6.682 + 0.492(X_2) + 0.715(X_3). It means that the educational level (X_2) and average monthly income (X_3) are two independent variables in positive relations with the efficiency of warehouse management. Specifically, one-unit higher in the educational level and average monthly income each correspond to the efficiency of the online warehouse management. Notably, the average monthly income is more related, which means it had the higher levels of income that associated with more number of people, which were efficient. This gives a clear indication of the optimizing tendency of warehouse management in relation to socioeconomic factors.

Table 2: Internal factors associated with the efficiency of online warehouse management

	B	*SE*	Beta	*t*	Sig
Constant	4.233	0.378		11.198	<0.001**
Receiving Goods Periods (X4)	-0.017	0.27	-0.028	-0.603	0.547
Storage Arrangements (X5)	0.144	0.092	0.109	1.568	0.119
Storage Costs (X6)	-0.529	0.029	0.923	-18.219	<0.001**
Outbound Distribution (X7)	0.45	0.035	-0.072	1.302	0.195
Product Holding Period (X8)	-0.215	0.044	-0.304	-4.84	<0.001**
R = 0.90 R^2 = 0.82 Adjusted R^2 =0.82 SEE= 0.28					

Table 2 shows the contribution of the internal factors to an equation that models the relationship between them and efficiency in the management of the warehouse as shown: Efficiency = 4.233 - 0.529(X_6) - 0.215(X_8). It shows that storage costs (X_6) and the period of inventory holding (X_8) both are inverse variables to the efficiency in online warehouse management. To be more specific, when the storage cost increases along with a longer period of holding inventory, efficiency is decreased. Conversely, efficiency gains are normally manifested through lower storage costs and a reduced holding period for the inventory. This relationship underscores the crucial role of cost management and turnover in ensuring that warehousing operations are optimized.

Table 3: External factors associated with the efficiency of online warehouse management

	B	*SE*	Beta	*t*	Sig
Constant	6.07	0.38		16.08	<0.001
Demand for goods (X9)	-0.53	0.79	-0.49	-6.69	<0.001
R = 0.50 R^2 = 0.25 Adjusted R^2 =0.24 SEE= 0.57					

From Table 3, equation modeling the relationship with the efficiency of online warehouse management is expressed as: Efficiency = 6.07 - 0.53(X9). This relationship shows that the demand for goods (X9) inversely affects warehouse management efficiency. An increase in demand for goods typically leads to a reduction in efficiency, primarily due to the need for higher inventory reserves, which can impact both storage costs and inventory holding periods. Consequently, optimizing inventory levels to maintain an adequate reserve without overstocking becomes crucial. This strategy is essential for minimizing costs and addressing forecasting inaccuracies in the demand for online fashion products, thereby enhancing warehouse management efficiency.

Qualitative data analysis

In small group interviews, two major challenges came out clear in online warehouse management. The first one is the issue of discrepancies in stock levels recorded in the system against those in a physical form, which causes overstocking of some products. Frequently, high-value items were stored without appropriate care, and some products deteriorated, considering the absence of systematic inspection and rotation. Second, the understocking of some items will have a result in that around promotional periods, demands cannot be met.

The above challenges were handled through the synthesis of qualitative data and with the application of the ABC-XYZ analysis in classifying the products according to their importance for determining how frequently inspection intervals should be made. For the second issue, analysis of retrospective sales data has been used to offer the most appropriate demand forecasts tailor-made to an online car accessories business for the maintenance of adequate levels of stock. In case of products with low demand, there was strategy reduction of inventory, therefore reducing the cost.

The ABC-XYZ Analysis Automotive accessories sales data from January 2022 to December 2023 have been classified based on the ABC and XYZ analyses with an objective to come out with better prioritization. Products were largely dominated in BX and CY categories at 26% of the overall stock, followed by the CX and BY categories at 18% and 10%.

This classification helps in the formulation of policies since it gives, with precision, the frequency of inventory checks and setting the reserve levels optimally to cost-effectively order and generate new order points for online warehouses. Forecasted from these first five AX-AY groups were further utilized to refine the organization of the product system.

Time Series Forecasting with the Moving Average

In the forecast using the Moving Average method, it was evidently established that the least error in forecasting was incurred in product code CB014, which stood at a 2-period movement. Also, a 4-period movement was at its best for product code CB013 in the forecast made using the same Moving Average model.

Table 4: Suitable variable values for the Moving Average method

Moving Averages		Compare the deviation values of product forecasting CB006	CB007	CB013	CB014	ME006
Length=2	MAPE	39.9	18.0	17.6	15.6	24.4
	MAD	53.7	35.9	128.4	122.8	18.4
	MSD	4459.2	2169.3	20336.2	27451.0	424.9
Length=4	MAPE	31.5	17.5	14.8	15.8	24.3
	MAD	40.8	34.7	104.4	118.1	17.8
	MSD	2961.0	2058.8	18072.0	23569.8	419.4
Length=6	MAPE	30.4	14.6	16.4	20.5	24.9
	MAD	43.7	33.5	112.8	156.2	18.2
	MSD	3541.9	1883.6	19827.4	39621.0	440.8

In the table above, the average error in the forecast has been expressed as an average percentage. In this sense, the lower, the better when considering this value with respect to forecasting accuracy. For instance, the MAPE for product CB006 improves with the lengthening of the moving average, i.e., best accuracy is met with the longest average. MAD (Mean Absolute Deviation) tells about the average of actual values' deviation from true values. Lower MAD values are desired, as in the case of MAPE. The MAD values show a trend of variation from product to product, but in general, they depict a decreasing trend with increasing moving averages, meaning the deviation of actual forecast is reducing. The squaring of the deviations before averaging emphasizes larger errors more than the smaller ones. The trends of MSD values are thus in general moving downwards for increasing lagged moving averages, reflecting fewer large errors on longer averages. Essentially, the table indicates that the increase in the length of the moving average gives rise to better forecasting in general. This could still be varied in effectiveness among these products, as seen by the different metric values within the listed products.

Time Series Forecasting with the Single Exponential Smoothing Method

Applying the Single Exponential Smoothing method to the sales forecast demonstrated that among the computed product codes, CB013 and ME006 have always been characterized by the smallest forecast error. This method is based upon one actual sales value and predictive data, which may change by reason of outside influence. Advanced analytic methods, combining all these strategic implementations, are intended to enhance the efficiency of inventory management in the warehouse, ensure an appropriate level of inventory, and streamline operations within the context of online business for car accessories.

Table 5: Suitable variable values for the Single Exponential Smoothing method

Single Exponential Smoothing		Compare the deviation values of product forecasting CB006	CB007	CB013	CB014	ME006
α (level) 0.2	MAPE	41.7	19.9	16.8	22.5	24.9
	MAD	56.7	42.3	117.7	172.8	18.1
	MSD	5448.43	2479.2	21631.0	47607.5	492.6
α (level) 0.4	MAPE	47.3	20.2	17.6	22.3	24.8
	MAD	60.4	41.2	127.1	171.7	18.6
	MSD	5722.2	2,700	24309.1	46105.9	500.1
α (level) 0.6	MAPE	51.3	21.4	19.7	21.6	25.8
	MAD	63.2	43.1	144.1	166.5	19.7
	MSD	6318.8	3102.1	27944.0	44007.8	543.4

Table 5 outlines the effectiveness of the Single Exponential Smoothing method in product forecasting across various α levels for products CB006, CB007, CB013, CB014, and ME006, each demonstrating different deviation values: At an α level of 0.2, CB013 exhibits the lowest MAPE at 16.8%, indicating the most accurate forecasting among the products, whereas CB006 shows the highest error rate at 41.7%. For MAD, which measures the average deviation from actual values, CB007 reports the smallest deviation at 42.3, suggesting more consistent forecast results, while CB013 has a much higher deviation at 117.7, indicating significant forecast variability despite its lower MAPE. MSD values are notably high for CB014 at 47607.5, reflecting a tendency towards larger forecast errors. Increasing the α to 0.4, the MAPE values slightly rise or stabilize for most products, except CB014 which sees a decrease, indicating a nuanced response to changes in α. MAD values generally increase, with CB013 notable for a sharp rise to 127.1. MSD values also rise across the board, suggesting that a higher α level tends to exacerbate larger forecast errors.

At an αlevel of 0.6, most products show a continued increase in MAPE, with the exception of CB014 which decreases to 21.6%. MAD values continue to rise for all products, with CB013 again showing a significant jump to 144.1, reinforcing the trend of increased deviation with higher α. Similarly, MSD values increase, indicating that larger errors become more prevalent as α increases.

Time Series Forecasting with the Double Exponential Smoothing

Table 6: Suitable variable values for the Double Exponential Smoothing method

Double Exponential Smoothing		Compare the deviation values of product forecasting CB006	CB007	CB013	CB014	ME006
α (level) 0.2	MAPE	45.4	18.4	16	25.9	21.2
γ (trend) 0.2	MAD	54.8	36.5	116.5	192.9	17.3
	MSD	4919.5	2341.0	22331.8	54819.9	389.2
α (level) 0.4	MAPE	51.8	20.2	18.3	25.9	24.5
γ (trend) 0.2	MAD	61.5	39.4	135.8	194.7	19.7
	MSD	6079.1	2886.1	27092.5	54038.7	485.9
α (level) 0.6	MAPE	56.0	22.2	21.0	24.0	26.9
γ (trend) 0.2	MAD	64.9	43.2	156.2	181.2	21.5
	MSD	7177.8	3465.6	31848.7	49663.3	583.9

Table 6 provides an analysis of the Double Exponential Smoothing method's performance across various products (CB006, CB007, CB013, CB014, and ME006) by adjusting the α and γ values, both set at 0.2. The data reveals that at an α of 0.2, CB013 achieves the most accurate forecasts with the lowest MAPE of 16.0%, whereas CB006 has the highest error rate at 45.4%. MAD and MSD values highlight CB007 as having the smallest deviation and CB014 the largest, indicating CB014's forecasts are less reliable. When α increases to 0.4, there's a general rise in MAPE for all products, suggesting less accuracy. This increase in α also causes a rise in both MAD and MSD for all products, except for a slight decrease in MSD for CB014, though it remains high. At an α of 0.6, the trend continues with further increases in error rates and deviations, especially notable in CB013, where MAD and MSD reach their peaks, suggesting significant inaccuracies in forecasting. Overall, higher α levels lead to increased forecasting errors, with each product showing different sensitivities to changes in α, underscoring the need for customized parameter settings in the Double Exponential Smoothing method to enhance forecast precision.

Time Series Forecasting with the Winters' Method

Table 7: Suitable variable values for the Winters' method

Winters' method		Compare the deviation values of product forecasting				
		CB006	CB007	CB013	CB014	ME006
δ = 0.2 (seasonal)	MAPE	30.4	14.6	14.8	15.6	15.7
	MAD	43.7	33.5	104.4	122.8	14.5
	MSD	3541.9	1883.6	18072.0	27451.0	244.6
δ = 0.4 (seasonal)	MAPE	51.2	18.9	19.9	24.8	16.8
	MAD	53.5	43.7	142.4	176.4	15.2
	MSD	5516.2	3215.4	32909.8	47996.6	263.9
δ = 0.6 (seasonal)	MAPE	53.7	19.1	19.9	25.8	19.0
	MAD	57.1	43.5	144.3	182.8	16.8
	MSD	6490.3	3501.9	35196.5	50948.7	322.9

In the table above for δ = 0.2, the MAPE shows considerable variability among products, ranging from a low of 14.6 for CB007 to a high of 30.4 for CB006, indicating the differences in prediction accuracy. MAD values also range widely, with ME006 showing the lowest deviation at 14.5 and CB014 the highest at 122.8. The MSD values further corroborate these findings, with ME006 having the least squared deviation at 244.6, while CB014 shows a substantial deviation at 27,451.0. Increasing δ to 0.4 generally results in higher deviation measures across all products, suggesting reduced forecasting accuracy. MAPE values increase across the board, with CB006 rising to 51.2 and ME006 increasing modestly to 16.8. MAD and MSD values escalate similarly, with CB014 displaying significant increases to 176.4 in MAD and 47,996.6 in MSD, highlighting greater forecast errors as δ increases.

Table 8: Compare the forecasting methods with the least error

Forecasting methods		Compare the deviation values of product forecasting				
		CB006	CB007	CB013	CB014	ME006
Moving Average	MAPE	39.9	18.0	17.6	15.6	24.4
	MAD	53.7	35.9	128.4	122.8	18.4
	MSD	4459.2	2169.3	20336.2	27451.0	424.9
Single Exponential smoothing	MAPE	41.7	19.9	16.8	21.6	24.9
	MAD	56.7	42.3	117.7	166.5	18.1
	MSD	5448.43	2479.2	21631.0	44007.8	492.6
Double Exponential smoothing	MAPE	45.4	18.4	16	24.0	21.2
	MAD	54.8	36.5	116.5	181.2	17.3
	MSD	4919.5	2341.0	22331.8	49663.3	389.2
Winters' method	MAPE	30.4	14.6	14.8	15.6	15.7
	MAD	43.7	33.5	104.4	122.8	14.5
	MSD	3541.9	1883.6	18072.0	27451.0	244.6

At δ = 0.6, the trend of increasing deviation values continues. MAPE reaches its peak for CB006 at 53.7 and remains elevated for other products like CB014 at 25.8. MAD and MSD follow a similar pattern, with CB014 recording the highest deviations at 182.8 and 50,948.7, respectively. These results illustrate that higher δ values tend to decrease the forecasting accuracy, leading to larger errors and greater deviations across all measured statistics.

Winters' Method in table 8 shows the highest accuracy among the forecasting methods, achieving the lowest MAPE values across most products, with the lowest MAPE of 14.6 for CB007. It also maintains lower MAD and MSD values, where the lowest MSD recorded is 244.6 for ME006, indicating a highly reliable forecasting capability. Conversely, the Moving Average method often records higher error values, with the highest MAPE reaching 39.9 for CB006 and the highest MSD observed at 27,451.0 for CB014, suggesting less precision in forecasting. The Single and Double Exponential Smoothing methods also show variability in their performance, but consistently, Winters' Method outperforms the other models by producing the smallest deviation values across the metrics, indicating its superior capability in handling seasonal variations and producing more accurate forecasts for inventory management.

DISCUSSION

The paper Improvement of Efficiency of Online Warehouse Management in the Automotive Accessories Sector in Thailand through ABC-XYZ Analysis and Forecasting Techniques is a good example of a research background that really sets the clear stage or backdrop against which several of the mentioned challenges and possible solutions for inventory management in emerging markets could be discussed. The following important issues are indicated from this case study: inefficient tracking of inventory values, lack of categorization of inventory, and depending on the experience of the distributor for forecasting orders, combine to become misaligned orders with customer demands. The argument resonates well with yang et al. (2022), who argue that clear, effective planning of the system and cost control are critical to an entity that will be successful at online inventory management.

Major factors found to affect the efficiency of warehouse management include the educational level, average monthly income, storage cost, the product holding period, and customer demand. This is commensurate with the study Bandoophanit et al. (2023) and Khathathornsapkul and Pisitkasem (2018), which elaborated that these factors take a very significant role in shaping inventory practices. The combination of ABC-XYZ analysis has proved to have multiples of benefits, which include cost reduction and enhancement in operational clarities. This translates to significantly lower costs than it would have been with either ABC or XYZ individually (Arbi et al. 2023).

Further, the usage of these forecasting techniques, more specifically the Winters' method, has really borne fruits in terms of significantly reducing product holding time, storage costs, and ordering costs which have been reported to decrease fairly large numbers after their implementation. This substantiates the findings of the research by Wahedi et al. (2023), who also emphasized the efficacy of precise demand forecasts in minimizing excess stock and optimized inventory costs.

It is in this geographical context of Thailand—one among the nerve centers of automotive manufacturing and export in Southeast Asia—where this study is relevant. Thus, it becomes an important area for applying advanced warehouse management techniques since specific economic policies and business environments in Thailand have a direct effect on logistic and supply chain strategies. This study's findings are, therefore, only expected to apply to other economies so long as these have similar emerging markets and exhibit parallel economic dynamics.

Research works including that of Ramos et al. (2020) and Lee and Kang (2018) reflect practical benefits of combination lean inventory techniques with modern Warehouse Management Systems (WMS) and advanced forecasting methods that result in improved operational efficiencies. This does not only facilitate in the understanding of product importance and demand variability but also enhances the accuracy of the prediction of future trends, hence supporting a more sharpened practice in inventory management.

In other words, integration of ABC-XYZ analysis to the advanced forecasting techniques in the online management of the warehouse is not fixing current inefficiencies but at the same time setting a framework for the continuity of betterment in response times and operational decisions in industries that are extremely dynamic, just like that of automotive accessories in Thailand. The significance of the case study is that it provides key lessons relating to flexibility and effectiveness of such methodologies in furthering improvements to inventory management practices, and is therefore a major contribution to the broader discourse on optimization of supply chains in emerging markets.

Theoretical and practical implications

This research has the practical implementation of the benefits derived from merging the ABC-XYZ analysis with forecasting techniques in online warehouse management within the case study area of Thailand's automotive accessories industry. It indicates that categorization of inventory, together with demand forecasting, has been integrated to improve warehousing efficiencies. This means that multifaceted management approaches benefit from the benefit of complicated inventory systems.

According to him, research shows that ABC-XYZ analysis gets out from the traditional application in manufacturing into the online environment; hence, it is applicable in different economic sectors and relevant to the peculiarities of the digital inventory management system. It adds validity on Winters' method for online inventory management, most especially on how seasonality and promotions are handled, advancing theoretical insight of forecasting model selection for industry needs.

Empirically, it has been revealed that implementation of these theoretical models can substantially reduce the cost while augmenting the manner of operational efficiency. In real sense, it offers business advice that makes them improve their inventory management practice using modern analytical and forecasting tools, hence reducing costs in storage, minimizing the time of holding products, and improving processing of orders. For managers and policymakers, more especially in Southeast Asia, such findings would lend a needful aspect of credibility to their strategic decision-making and policy formulation that may enhance competitive advantage and customer satisfaction in the hyper-dynamic online retail space.

Limitations and future directions

The study primarily focuses on Thailand's automotive accessories sector, which may limit the generalizability of the findings to other regions or sectors. Future studies could explore similar models in different geographical locations and industries to validate the findings more broadly. The effectiveness of ABC-XYZ analysis and forecasting techniques heavily relies on the quality and granularity of the data used. In scenarios where data integrity is compromised, the results may not be as reliable. Ensuring data accuracy remains a challenge that needs addressing in future implementations. The study assumes a level of technological infrastructure that may not be present in all potential application settings, especially in less developed markets. This could affect the scalability of the proposed methods. While the integration of advanced forecasting methods like Winters' method offers significant benefits, the complexity and the need for specialized knowledge may hinder its adoption in smaller enterprises or those with limited technical expertise.

Future research could replicate this study in different countries or across different sectors to examine the universality of the ABC-XYZ analysis combined with forecasting techniques. This would help understand its effectiveness across various market dynamics and economic environments. Exploring the integration of artificial intelligence and machine learning could enhance the forecasting accuracy and inventory management capabilities. Machine learning models could be developed to predict more complex patterns and seasonal variations with higher precision. Conducting longitudinal studies could help in understanding the long-term impacts of implementing ABC-XYZ analysis and forecasting techniques in warehouse management. This would provide insights into the sustainability of cost reductions and efficiency improvements over time. Applying the ABC-XYZ analysis and forecasting methods to other industries like pharmaceuticals, electronics, or consumer goods could provide deeper insights into the versatility and limitations of these methods. Developing more user-friendly software solutions and providing comprehensive training programs could facilitate the adoption of advanced inventory management techniques among smaller and less technically-sophisticated businesses.

CONCLUSIONS

This study has successfully demonstrated the effectiveness of integrating ABC-XYZ analysis with forecasting techniques in enhancing online warehouse management, specifically within Thailand's automotive accessories sector. The application of these methodologies has led to significant improvements in operational efficiency, reduced costs, and better alignment of inventory with demand. The use of Winters' method, in particular, has proven valuable for managing seasonal variations and ensuring timely responses to market dynamics.

The findings suggest that such integrated approaches can be extended beyond traditional manufacturing settings to online environments, offering broad applicability across various economic sectors. For managers and policymakers, especially in Southeast Asia, this research provides actionable insights for strategic decision-making and policy development aimed at optimizing inventory systems and improving competitive advantage.

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