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Exploring managerial insights through multi criteria decision making techniques in pharmacy inventory classification problem

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A B S T R A C T

The current research addresses the inventory classification problem of community pharmacies, which have a dual role as both a vital component of the pharmaceutical supply chain and a typical retail store. Despite the existing literature indicating that pharmacists may lack knowledge on inventory management, it seems that the MCIC literature is weak in explaining how pharmacists can benefit from MCDA techniques in all aspects. To bridge this gap, the study aims to demonstrate that pharmacists can utilize MCDA techniques to gain deeper insights beyond mere classification in the context of inventory management. Real-world data from a community pharmacy in Turkey was classified using the EDAS method. Sensitivity analysis was performed for MCDA inputs, about which pharmacists may lack information. Scenario findings based on criterion weights and threshold values offer important managerial implications for pharmacists. This study provides a critical contribution to the literature on inventory management in community pharmacies by highlighting the potential of MCDA techniques to support decision-making beyond mere classification. The sensitivity analysis also sheds light on areas where pharmacists may lack knowledge and suggests ways to address these gaps. Overall, the study underscores the need for pharmacists to have a deeper understanding of inventory management and highlights the potential benefits of MCDA techniques in addressing this challenge.

1. Introduction

Inventory management is a key issue in all business model (Wild, 2017), involving the procurement of stock keeping units (SKUs) at the appropriate quantity, time, and price (Richard, 2003). To prevent stockouts and potential losses in sales and customers, decision-makers tend to overstock (Matopoulos & Michailidou, 2013). However, excessive inventory can lead to opportunity costs and the risk of waste, such as spoilage and obsolescence. In the healthcare industry, any failure in inventory management can have grave consequences beyond financial losses, such as interruptions in treatment processes, deterioration of patient health status, and even fatalities (Hidayat et al., 2020). This highlights the importance of effective inventory management at all stages of healthcare service delivery.

Pharmacies play a critical role in the pharmaceutical supply chain of any healthcare system, with the responsibility of the uninterrupted supply of medicines (Elarbi et al., 2020). However, they also function as retail stores with economic concerns, offering medicines and other health-related products. This dual role creates a need for pharmacies to optimize inventory management. Despite this need, pharmacists, who are typically responsible for managing pharmacies, are trained primarily in pharmacy rather than inventory management. The findings of Maharaj et al. (2020) and Rollins et al. (2012) highlight a significant oversight in pharmacy education, namely the inadequate coverage of essential business management subjects, such as inventory management, human resource management, and cash flow management, in the curriculums of pharmacy

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schools. These studies reveal a critical need to incorporate these vital business skills into pharmacy education to equip future pharmacists with the knowledge and skills necessary for successful business practice. Recent studies by Ighorodje & Ola-Olorun (2019) and Jobira et al. (2022) further indicate that pharmacists possess limited knowledge of inventory management. Consequently, pharmacists may lack the expertise to effectively manage a large number of items.

In the field of operations management, decision makers are presented with numerous options to effectively manage inventory. To accomplish this, inventory classification techniques are employed to group items with similar attributes, allowing for streamlined management under a shared policy (Chakravarty, 1981). The well-known inventory classification approaches ABC VED, and FNS consider cost, criticality, and consumption rate factors respectively (Parekh et al., 2008). The matrix approach, which employs a combination of single-criteria methods, is frequently utilized for efficient inventory control. Notable examples of this approach include the ABC-VED matrix (Kumar & Chakravarty, 2015), FSN-VED matrix (Bošnjaković, 2010), ABC–VED–FNS matrix (Gizaw & Jemal, 2021; Sheikhar & Matai, 2022). Single-criterion inventory classification approaches are predicated on sorting items based on their performance on the relevant criterion and categorizing them according to the Pareto principle (Dickie, 1951). The classification process is completed by combining the results of two different single-criteria classification techniques in matrix format by executing a few simple logical operations. Given the lack of knowledge of pharmacists in inventory management, single-criteria matrix approaches are attractive because they are simple, easy to implement and understandable. However, in many cases, like pharmacy inventory classification, various criteria such as shelf life, cost, lead time and demand need to be considered simultaneously (Ramanathan, 2006; Zhou & Fan, 2007). Thus, it may be contended that single-criterion inventory classification approaches are unsuitable for pharmacists and may even be disadvantageous.

The state of the art in inventory classification approaches allows multiple factors to be considered simultaneously. Among these approaches, Multi-Criteria Decision Analysis (MCDA) stands out, which allows the performance of each SKU on various factors to be represented in a single relative score, taking into account the importance of the factors (de Assis et al., 2020). MCDA techniques, which are not as simple as single-criteria classification approaches, give effective results in inventory classification problems (van Kampen et al., 2012). In parallel, the multi-criteria inventory classification (MCIC) literature contains sufficient studies on how to classify inventory using MCDA techniques in healthcare (Ali, 2011; Saha & Ray, 2019). Therefore, theoretically, it can be claimed that there is no obstacle for pharmacists to use MCDA techniques in inventory classification. Belton & Stewart (2002) assert that the effective implementation of MCDA in practical settings is contingent on the decision-makers' aptitude to acquire the necessary skills to utilize the approach proficiently, even in the absence of technical expertise in MCDA. From this standpoint, it can be contended that the literature on MCIC in healthcare fails to adequately address the challenges facing decision-makers with limited technical expertise and knowledge, such as pharmacists, in accessing valuable managerial insights beyond the mere application of classification. Therefore, there is a need for further research that explores the practical implications of MCDM in real-world decision-making contexts, including strategies that can facilitate the implementation of MCDM techniques by non-expert decision-makers in the healthcare industry. This research endeavors to address this gap by proposing an approach that enables pharmacists to extract deeper insights from MCDA techniques in the context of inventory classification. Specifically, this approach seeks to enable pharmacists to use MCDA techniques more effectively to optimize inventory utilization, rather than solely relying on MCDA techniques for classification purposes.

The classical MCDA approach comprises three fundamental components: firstly, the identification of alternatives (SKUs) and criteria (classification factors) relevant to the decision-making process. Secondly, the approach involves determining the relative significance of each criterion (criteria weights), as well as evaluating the performance of the alternatives concerning each criterion (decision matrix). Finally, an algorithm or method is utilized to calculate the relative score of each alternative, which allows for the comparison and selection of the most suitable alternative(Triantaphyllou, 2000). These inputs can vary based on the decision-maker's judgment and experience, making sensitivity analysis a crucial step in MCDA (Triantaphyllou & Sánchez, 1997). Sensitivity analysis helps to determine the extent to which the output depends on the inputs, (Rios Insua, 1999), which is advantageous when monitoring the impact of variability in inputs on classification (Iooss & Lemaître, 2015). This approach eliminates the need for precise specification of inputs (Saltelli et al., 1999) and addresses the uncertainty resulting from the decision-maker's lack of familiarity with the classification problem (Durbach & Stewart, 2012). Although varying inputs may appear as a weakness at first, sensitivity analysis turns it into an opportunity to better understand and manage the problem. Therefore, when the classification performed with a MCDA approach is accompanied by a sensitivity analysis, the pharmacist's deficiencies in mastering the problem can be tolerated, and managerial implications can be obtained by illuminating the hidden aspects of the problem. Consequently, MCDA with sensitivity analysis enables decision makers to assimilate the problem by understanding the impact of different inputs.

In this context, pharmacists' motivation to perform sensitivity analysis can be attributed to two critical factors. The first factor is criteria weights, which determine the extent to which the performance of SKUs on each criterion is reflected in the classification. These weights may vary based on the pharmacist's experience, perspective, or seasonal changes. Testing the classification process with different sets of weights representing various perspectives can help assess the consistency of SKUs in their respective classes. The second factor is class thresholds, which are critical in every inventory classification problem, irrespective of the classification approach used. SKUs are categorized into classes based on class thresholds, and different threshold values can result in SKUs being placed in different classes. Pharmacists may want to examine the effect of different threshold values on classification to ensure accuracy.

This study deals with the pharmacy inventory classification problem in the case of community pharmacists. The inventory classification problem in community pharmacies presents unique challenges (Ali, 2011; Piquer-Martinez et al., 2022) compared to the classical pharmacy inventory classification problem. In the typical pharmacy inventory classification problem, pharmacists evaluate pharmaceutical inventory items based on multiple criteria. However, in the community pharmacy setting, additional factors such as the demographic structure of the local population, prevalent diseases, drug consumption patterns, purchasing power, profitability, and the need to optimize capital may influence inventory classification. Therefore, effective inventory classification requires comprehensive consideration of these dimensions.

This study presents an investigation into the managerial information that a MCIC approach can offer pharmacists beyond simple classification results, in the context of community pharmacy inventory classification problem. The study utilizes real-world data from a pharmacy in Gaziantep, Turkey, operating under intense competition and the EDAS method as the MCDA technique for inventory classification. Sensitivity analysis was conducted using a total of nine scenarios over three different sets of weights and thresholds. The findings from the scenarios provide useful managerial implications that can enhance a pharmacist's ability to solve the problem.

The contributions of this study are threefold. First, it expands the use of MCDA approaches in the MCIC literature. Second, it provides pharmacists with the opportunity to uncover information that can enhance their managerial skills in inventory classification. Third, it highlights the community pharmacist inventory classification problem as a promising area for further research.

The remainder of the paper is organized as follows: Section 2 presents the study's background by referring to related research. Section 3 provides details of the case, including the methodology and data analysis. Finally, in Section 4, the conclusions and recommendations are discussed.

2. Related Studies

The present study focuses on two primary aspects, specifically, (i) the implementation of MCDA for inventory classification and (ii) the classification of inventory in community pharmacies. The purpose of this section is to highlight the unique contributions of the study in each of the aforementioned domains, based on the relevant literature.

(i) The utilization of multi-criteria decision analysis for inventory classification

The effective management of inventory is essential for businesses to maintain their competitive edge in the market. Multi-Criteria Inventory Classification (MCIC) approaches have emerged as a valuable tool to aid in this process by considering various criteria to guide inventory management decisions. The classification approach involves aggregating the performance of multiple criteria, which can be achieved through the use of Artificial Intelligence algorithms, DEA-like optimization models, and Multi-Criteria Decision Analysis (MCDA) techniques. This study specifically focuses on the MCDA branch.

Flores and Clay Whybark (1986) laid the foundation for multi-criteria classification by proposing that additional criteria, including lead time and criticality, could augment the ABC classification. To synthesize multiple criteria into a consistent univariate measure, Flores et al. (1992) advocated for the use of the Analytic Hierarchy Process (AHP). The classification outcomes and data set presented by Flores, Olson and Dorai (1992) have become the standard for subsequent research in MCIC, as evidenced by ongoing studies such as Partovi and Burton (1993), Gajpal, Ganesh and Rajendran (1994), and Partovi and Hopton (1994). These studies illustrate how MCDA techniques can be applied to inventory classification issues.

The groundwork for multi-criteria classification was laid by Flores and Clay Whybark who suggested that ABC classification could be enhanced by considering additional criteria, such as lead time and criticality. Flores et al. (1992) further proposed the use of the Analytic Hierarchy Process (AHP) to reduce these multiple criteria to a univariate and consistent measure. The data set and classification results presented by Flores, Olson and Dorai (1992) serve as a benchmark for subsequent MCIC research, as exemplified in ongoing studies such as those by Partovi and Burton (1993), Gajpal, Ganesh and Rajendran (1994), and Partovi and Hopton (1994). These studies demonstrate the application of MCDA techniques to inventory classification problems.

MCDA techniques are based on three primary approaches: Full Aggregation (A), Outranking (B), and Reference Level (C). These approaches differ in their benefits and drawbacks and are influenced by the decision-makers' discernment of alternatives. A and B employ contradictory rationales. A allows an alternative's inferior performance on one criterion to be offset by its superior performance on another criterion, whereas B does not. C is positioned between the two. B requires more information and has a more complex algorithm than A. The modification of both of A and B methods is necessary to suit the inventory classification problem. Some are as follows. To overcome the disadvantage of A, Lolli (2014) proposed an AHP-based veto approach that prevents the misclassification of SKUs by preventing a SKU that is rated high/bad in at least one criterion from being ranked high/low in the global aggregation. Douissa & Jabeur (2020) proposed a simplified Electre III based approach to avoid the misclassification of SKUs using the non-compensatory procedure of B and used a variable neighbor search algorithm to estimate the required parameters.

Ghorabaee et al. (2015) proposed a new methodology named Evaluation Based on Distance from Average Solution (EDAS) with Reference Level, specifically designed to address the multi-criteria inventory classification problem. The EDAS approach utilizes positive and negative distances from the average solution to assess SKUs and is characterized by its simple algorithm. The specificity of EDAS to the inventory classification problem makes it a valuable tool in this study.

Sensitivity analysis plays a crucial role in MCIC, particularly for pharmacists. This argument is supported by several studies in the inventory classification literature. Hincapie et al. (2011) conducted a comprehensive inventory classification study in the oilfield equipment industry, which placed exclusive emphasis on sensitivity analysis. The study employed sensitivity analysis to gain managerial insights into potential problems arising from a failure to produce all essential parts within the stipulated time frame. Iqbal et al. (2017) statistically analysed the performance of classification methods in the case of demand growth. The research incorporates a sensitivity analysis aimed at identifying the MCIC model that exhibits a statistically significant performance concerning inventory management and customer order fulfilment rate. Lolli et al. (2017) proposed a comprehensive framework for the concurrent selection of an item classification methodology through the consideration of multiple criteria. The authors employed a sensitivity analysis to assess the influence of weights attributed to significant performance indicators, thus enhancing the robustness and accuracy of their approach. These studies highlight the importance of sensitivity analysis in gaining managerial insights into potential problems. Thus, sensitivity analysis is a complementary element of inventory classification and an important instrument for providing managerial insight.

(ii) The classification of inventory in community pharmacies

Saha and Ray's (2019) literature review underscores the varied challenges related to inventory management in healthcare and the plethora of management science tools available to tackle these issues. The review identifies ten factors that impact inventory management, linking inventory type with the inventory classification process, and explores the inventory classification problem in hospital pharmacies. The history of hospital pharmacy management research dates back to the 1960s (SALLEE, (1958)). Noel's study (1984) emphasized that inventory managers could enhance hospital cost-effectiveness through inventory classification, which remains the fundamental driver of pharmacy inventory management research to this day (Ahmadi et al., 2022; Saha & Ray, 2019).

The vast majority of research has focused solely on hospital pharmacies, disregarding community pharmacies, which constitute an essential component of the pharmaceutical supply chain in all healthcare systems. However, given the differences in healthcare roles (Nagappa & Naik, 2022) and commercial concerns (Gammie et al., 2016) between community and hospital pharmacies, the inventory management of community pharmacies is a crucial topic for investigation.

Although few studies have delved into community pharmacy inventory management, Parrish et al. (1986) conducted a study in Alabama community pharmacies to investigate the correlations between profitability, inventory turnover, and gross margin return on investment. Komjathy (2016) analyzed the financial development of Slovakian community pharmacies from 2009 to 2014. delved into the tactics and resources utilized by community pharmacists in order to effectively address a common scarcity issue. Timoteo (2022) examined how community pharmacists navigate disparities between sales and inventory. However, as far as we know, the inventory classification problem of community pharmacies remains unexplored in the literature, despite the unique characteristics of these pharmacies, which make it a promising avenue for future research.

3. Case Details

In this case, the pharmacy is located in close proximity to other pharmacies near a hospital, creating a highly competitive environment where customer loyalty is crucial. Meeting customer demand is deemed the most effective strategy to ensure customer satisfaction and prevent the loss of customers and revenue. However, maintaining a large inventory of each drug to avoid stockouts may lead to high opportunity costs, particularly for low-demand, high-cost drugs that run counter to rational inventory management practices. Despite this, the strategy of stocking such drugs may be justified by the potential to enhance customer loyalty by fulfilling a demand that competitors cannot meet.

In addition, profitability plays a significant role in inventory management decisions for the pharmacy. It is important to ensure that drugs with high-profit margins do not run out of stock. Although the pharmacy can supply exhausted medicine during the day, it may lose revenue even in the brief time required for supply, given the location of the pharmacy. This underscores the importance of taking different criteria into account when classifying the pharmacy's inventory, as compared to a typical inventory classification problem.

To establish suitable criteria for inventory classification, an analysis was conducted on the pharmacy's database, which encompasses data on purchase price, selling price, and quantity in stock for 1,139 items. The selection of the following criteria was based on this analysis:

- Cost: Purchase price. To include opportunity cost, which is a very important element in inventory control, in the classification decision.
- Demand: Quantity in stock. As stated by the pharmacist, it is directly linked to demand. To include its significant impact on the traditional classification standard and inventory classification.
- Profit Rate: (Selling price - Purchase price) / Purchase price. To integrate the profit rate into inventory management due to the fact that community pharmacies function as commercial enterprises.

Table 1 presents the summary statistics of the data.

Table 1
The summary statistics of the data

#	Barcode	Cost (TL)	Demand	Profit Rate
1	8697928020122	120,06	1	37%
2	8697943590020	44,23	1	38%
3	8698747570027	18,26	142	38%
4	8699819010076	36,48	140	38%
⋮	⋮	⋮	⋮	⋮
1136	8699856710045	105,77	7	38%
1137	8699874080120	270,41	1	31%
1138	8699874080359	32,08	5	38%
1139	8699976091192	101,85	3	38%
	Maximum	1.643,91	358,00	300%
	Minimum	4,00	1,00	4%
	Standard Deviation	82,95	16,41	13%
	Average	51,67	6,55	40%

We determined the criterion weights and class thresholds for classification through the following process. It appears that the pharmacist does not possess a clear understanding of the appropriate weights for the criteria. Therefore, we attempted to create weight sets using different techniques (as shown in Table 2). For W1, we assumed that all criteria were equally significant. In W2, we employed the best and worst method, which was based on the pharmacist's subjective evaluations, to establish the weight set. In W3, we calculated the average of the weights obtained through objective weighting techniques, such as CRITIC and ENTROPY methods.

Table 2
Weight sets

	Cost (TL)	Demand	Profit Rate
W1	33%	33%	33%
W2	14%	57%	29%
W3	35%	47%	17%

The challenge of determining the appropriate values for class thresholds is compounded by the pharmacist's inability to provide an opinion. Unlike criterion weights, there is no standardized technique for calculating thresholds. Consequently, in line with the underlying logic of the ABC classification, three sets of thresholds were established manually and are presented in Table 3. The first set, T1, is based on ranking products in descending order of importance. Under T1, the top 10% of products are classified as A, the subsequent 30% as B, and the remaining products as C.

Table 3
Threshold sets

	T1	T2	T3
A	10%	15%	20%
B	30%	25%	30%
C	60%	60%	50%

When the predetermined weight and threshold sets for classification intersect, nine distinct scenarios arise that require analysis (Table 4). It is worth noting that the majority of these scenarios are the result of the pharmacist's inability to distinguish the critical parameters necessary for classification. Consequently, an examination of these scenarios can offer valuable managerial insights into the effects of parameter alterations on classification.

Table 4
All scenarios

	T1	T2	T3
W1	S1	S2	S3
W2	S4	S5	S6
W3	S7	S8	S9

4. Methods

The present study employed the EDAS method to undertake a multi-criteria inventory classification process. To ensure the accuracy and validity of the results, the criteria weights were determined by utilizing the BWM, CRITIC, and ENTROPY methods. The underlying principles and mechanics of these methods are elaborated upon in the subsequent section. By utilizing a comprehensive set of methodologies, this study aimed to provide a robust and reliable classification framework for inventory management.

4.1 EDAS Method

The methodology proposed by Ghorabaee et al. (2015), known as EDAS, adopts an approach that centers around the computation of the distance between alternatives and the reference solution point. The present technique exhibits similarities with conventional approaches employed in the domain of multi-criteria decision-making, specifically with the TOPSIS and VIKOR methodologies. However, EDAS distinguishes itself from these approaches by determining the reference solution point using the mean value instead of extreme values within the criteria.

In this paper, we outline the EDAS method, which consists of a series of steps.

Step 1: The alternatives and the evaluation criteria are determined.

Step 2: The decision matrix (X) is constructed.

Where n is the # of alternatives, m is the # of criteria and X_{ij} is the performance of alternative i on criterion j, the decision matrix is expressed as follows.

$$X = \left[X_{ij}\right]_{nxm} = \begin{bmatrix} X_{11} & \cdots & X_{1m} \\ \vdots & \ddots & \vdots \\ X_{n1} & \cdots & X_{nm} \end{bmatrix}$$

Step 3: The average solution is determined for all criteria.

$$AV = \left[AV_j\right]_{1xm} \rightarrow AV_j = \frac{\sum_{i=1}^{n} X_{ij}}{n}$$

Step 4: The positive distance (PDA) and negative distance (NDA) of the alternatives from the mean are calculated according to the criterion orientation (benefit and cost).

$$PDA = \left[PDA_{ij}\right]_{nxm}, NDA = \left[NDA_{ij}\right]_{nxm}$$

If criterion j is utility orientated;

$$PDA_{ij} = \frac{max\ (0, (X_{ij} - AV_j))}{AV_j}, NDA_{ij} = \frac{max\ (0, (AV_j - X_{ij}))}{AV_j}$$

If criterion j is cost orientated;

$$PDA_{ij} = \frac{max\ (0, (AV_j - X_{ij}))}{AV_j}, NDA_{ij} = \frac{max\ (0, (X_{ij} - AV_j))}{AV_j}$$

Step 5: Determine the sum of weighted PDA and NDA for all alternatives.

The values of SP_i and SN_i, where w_j is the weight of criterion j, are calculated as follows.

$$SP_i = \sum_{j=1}^{m} w_j PDA_{ij}, SN_i = \sum_{j=1}^{m} w_j NDA_{ij}$$

Step 6: Normalise the SP and SN values for all alternatives.

$$NSP_i = \frac{SP_i}{\max(SP)}, NSN_i = 1 - \frac{SN_i}{\max(SN)}$$

Step 7: Calculate the evaluation score (AS) for all alternatives.

It is calculated as follows with $0 \leq AS_i \leq 1$.

$$AS_i = \frac{(NSP_i + NSN_i)}{2}$$

Step 8: Alternatives are ranked in descending order of AS score.

4.2 Best and Worst Method

The BWM methodology, originally proposed by Rezaei (2015), is a multi-criteria decision-making approach that aims to provide a reliable and consistent evaluation of alternative options. Unlike other comparable methodologies, the BWM technique relies on pairwise comparisons and is known for its ability to produce more accurate and reliable outcomes, particularly when a significant number of pairwise comparisons are made. The BWM approach involves a set of sequential steps that systematically guide the decision-making process. These steps include:

Step 1. Determination of best (B) and worst (W) criteria

Step 2. Determining the level of preference of the best and worst criteria over other criteria

1-9 scale is used. (1: Equal importance, 5: Strongly more important, 9: Absolutely more important)

$$A_B = (a_{B1}, a_{B2}, a_{B3}, \dots, a_{Bn})$$

$$A_W = (a_{1W}, a_{2W}, a_{3W}, \dots, a_{nW})^T$$

a_{Bj} indicates the preference of the best criterion B over criterion j.

a_{jW} indicates the preference of the criterion j over the worst criterion W.

Step 3. The optimal w is obtained by solving the following mathematical model.

$$\min \xi$$

$$\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \xi, \left|\frac{w_j}{w_w} - a_{jw}\right| \leq \xi$$

$$\sum_j w_j = 1, w_j \geq 0 \; \forall j$$

Step 4. Calculate the consistency ratio

$$Consistency\ Ratio = \frac{\xi}{Consistency\ Index}$$

The consistency index is determined according to Table 5.

Table 5
Consistency Index Table

a_{BW}	1	2	3	4	5	6	7	8	9
Consistency index	0.00	0.44	1.00	1.63	2.30	3.00	3.73	4.47	5.23

4.3 CRITIC and ENTROPY Methods

CRITIC (Diakoulaki et al., 1995) and ENTROPY (Wang & Lee, 2009) methods are two distinct approaches for obtaining objective weights of criteria in decision-making. The CRITIC method utilizes standard deviations of the criteria and correlations between them to determine the weights, while the ENTROPY method focuses on the differentiation among criteria and employs a series of stages to derive objective weights using the information within the decision matrix. Both methods provide quantitative tools to objectively determine the importance of criteria in decision-making.

5. Findings

The current study first examines the viability of adopting the MCIC approach by pharmacists. To this end, the traditional cost-based single-criteria ABC classification methodology was compared with the EDAS classification approach. In the single-criteria classification, the total cost was obtained by multiplying the inventory amount by the cost. The T1 threshold serving as the basis for classifying the items. Table 6 illustrates the findings of this comparison in terms of the number of items allocated to the same category.

Table 6
Number of items assigned to the same classes in single-criteria and multi-criteria (EDAS) classifications

Scenarios with T1 threshold	S1	S4	S7
# of items not in the same class	192	243	188
# of items in the same class	947	896	951

The results indicate a clear distinction between the two approaches. In cases where the discrepancy is negligible (S1), a single-criterion ABC analysis may be sufficient, obviating the need for additional information and the computational complexities associated with multi-criteria decision-making techniques. However, the significant number of items that do not belong to the same class in S4, where the criteria weights are subjectively determined by the decision-maker, suggests that total cost alone is inadequate for comprehensive classification. In contrast, in S7, where the weights are determined based on data irregularities, the number of misclassified items is relatively low. Therefore, the multi-criteria approach proves to be a more robust and reliable method for inventory classification in scenarios where subjective judgments are involved.

Once the requirement for a multi-criteria inventory classification has been established, predicting the effects of factors beyond the pharmacist's expertise on the classification can be accomplished through an exhaustive analysis of all potential scenarios. This analysis is executed utilizing the threshold and weight axis. The importance of thresholds becomes apparent as the number of items in each class corresponds to the threshold ranges presented in Table 7. These thresholds exert a direct influence on the classification process by dictating the quantity of items assigned to each respective class. The capacity of pharmacists to effectively manage inventory resources can be linked to the number of items assigned to each class. For instance, a higher quantity of items assigned to class A denotes a more rigorous level of control, which is a desirable outcome. However, pharmacists who are limited by resource constraints may prefer fewer items assigned to this category. In such instances, pharmacists may opt to initially employ narrower thresholds and progressively broaden them as they acquire greater skill in managing inventory. If the inventory control process is associated with the workforce, a pharmacist with a large number of staff can afford to be more inclusive for Class A, while those with fewer staff should be more conservative.

Table 7
Number of items in classes by threshold

	T1	T2	T3
A	114	171	228
B	342	285	342
C	683	683	569

In order to comprehensively investigate the impact of weight sets on classification, an analysis of scenarios S1, S4, and S7 at threshold T1 can be conducted through pairwise comparison, as presented in However, the large number of items in different classes during the S1-S4 comparison indicates that the pharmacist's assessment of the criteria can have a significant impact on the classification. In such cases, it is recommended that the pharmacist use a variety of quantitative techniques, such as BWM, pairwise comparison, to incorporate their assessment of the criteria into the classification process, which can increase the accuracy and effectiveness of the classification.

Table 8. The limited number of items in different classes during the S1-S7 comparison indicates that it may not be necessary to use weighting methods based on variability in the data if the pharmacist cannot determine the importance of the criteria. In such cases, if criterion weights are accepted as equal, a close classification can be achieved without the need for additional calculations. However, the large number of items in different classes during the S1-S4 comparison indicates that the pharmacist's assessment of the criteria can have a significant impact on the classification. In such cases, it is recommended that the pharmacist use a variety of quantitative techniques, such as BWM, pairwise comparison, to incorporate their assessment of the criteria into the classification process, which can increase the accuracy and effectiveness of the classification.

Table 8
Pairwise comparisons of scenarios S1, S4 and S7 at threshold T1

	S1-S4	S4-S7	S1-S7
# of items in the same class	916	1006	1033
# of items not in the same class	223	133	106

The pairwise comparison in Table 8 highlights the importance of considering the impact of weight sets on classification, and emphasizes the need for pharmacists to carefully evaluate the significance of criteria and utilize appropriate techniques to incorporate their assessments into the classification process.

Through an analysis of multiple scenarios, one can draw conclusions about the reliability of classification. Statistical data presented in Table 9 displays the frequency with which items were classified in the same group across 9 distinct scenarios. For instance, class A included 86 items in all 9 scenarios, while no items were classified as class C in only one scenario. Based on the criterion that consistent classification is indicated by 7 or more items being classified in the same group, it can be inferred that a total of 930 items (approximately 82% of the entire inventory) were consistently classified. This finding strongly suggests that regardless of the scenario chosen by the pharmacist, the resulting classification is highly likely to be accurate. In short, if one of the scenarios is chosen randomly, many items in the classification will be correctly classified.

Table 9
Number of items assigned to the same class x times in 9 scenarios

x times	A	B	C
1	38	128	0
2	23	35	65
3	27	39	11
4	26	84	23
5	18	49	65
6	21	36	19
7	16	87	19
8	21	38	107
9	86	98	458

6. Conclusion

Inventory classification techniques are widely utilized to manage SKUs efficiently by grouping them based on shared characteristics under a common policy. Multi-Criteria Decision Analysis (MCDA) techniques are commonly employed in classification, as they allow for the consideration of multiple factors concurrently. Sensitivity analysis is an approach that eliminates the need for precise specification of MCDA inputs and reduces uncertainty due to decision makers' unfamiliarity with the classification problem.

However, pharmacists may not have the necessary expertise to accurately determine the inputs required for the MCDA approach to inventory classification. Sensitivity analysis can assist pharmacists in ensuring the accuracy of the classification process by utilizing different sets of weights representing various perspectives and observing the impact of different thresholds on classification. The objective of this study is to identify managerial insights that can be obtained from sensitivity analysis for the inventory classification problem in community pharmacies.

To achieve this goal, data collected from a Turkish pharmacy comprising 1139 items and three criteria: cost, demand, and profit rate, is utilized. The methodology employed includes the EDAS, BWM, CRITIC, and ENTROPY methods. This study first compares multi-criteria inventory classification with classical single-criteria ABC analysis. The results indicate that single-criteria ABC analysis is inadequate for the community pharmacy inventory classification problem, and pharmacists require multi-criteria inventory classification approaches.

Subsequently, the sensitivity of parameters that pharmacists may lack knowledge about regarding MCDA techniques is analyzed. The findings demonstrate that thresholds should be adjusted based on the pharmacist's inventory management abilities. Furthermore, the pharmacist's opinions regarding the criteria can influence the classification, and therefore, should be quantified and included in the classification using various techniques. Overall, the analysis of different scenarios indicates that pharmacists can perform a successful classification by utilizing the multi-criteria decision-making methodology.

In conclusion, this study highlights the importance of sensitivity analysis in assisting pharmacists with the accurate classification of inventory in community pharmacies. Additionally, it emphasizes the necessity of utilizing multi-criteria inventory classification approaches to better manage the diverse range of SKUs. In future research, decision support systems could be integrated to further investigate the community pharmacy inventory problem.

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