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ORIGINAL ARTICLE / ARAŞTIRMA YAZISI

Health Care Administration/Sağlık Hizmetleri Yönetimi

Optimizing Inventory Control in Emergency Health Services: A Case-Based ABC–VED Matrix Application

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ABSTRACT

Purpose: This study aimed to evaluate the inventory of medicines and disposable medical supplies in a Type A2 emergency health services station in Türkiye using ABC, VED, and ABC–VED matrix methods, and to propose strategies for optimizing stock control.

Methods: The study was conducted in 2024 at an A2-type emergency station in Kırklareli province. Annual consumption and cost data for 131 items were extracted from automation records. Criticality classifications (Vital, Essential, Desirable) were determined through structured interviews with eight experienced professionals. The combined ABC–VED matrix was used to identify high-, medium-, and low-priority groups for inventory control.

Results: The ABC analysis revealed that 12.21% of items (Category A) accounted for 69.32% of the total expenditure. VED analysis revealed that vital items comprised 55.73% of stock and 57.18% of costs. The integrated ABC–VED matrix indicated that the high-priority group (AV, AE, BV) comprised only 33 items but accounted for 73.15% of total expenditures, underscoring their critical clinical and financial significance. Medium-priority items (71% of stock) had a limited cost impact but a high operational volume. Low-priority items, though few in number, represented 10.3% of costs.

Conclusion: Emergency health services require inventory strategies tailored to their unique logistical and clinical demands. The ABC–VED model provides a dual framework for balancing cost efficiency with clinical necessity, ensuring uninterrupted availability of life-saving materials. Integrating matrix-based protocols into regional and national EMS logistics could enhance efficiency, readiness, and patient outcomes.

Keywords: Emergency health services, Inventory management, ABC analysis, VED analysis, ABC–VED matrix

ÖZET

Amaç: Bu çalışma, Türkiye'de A2 tipi bir acil sağlık hizmetleri istasyonunda kullanılan ilaçlar ve tek kullanımlık tıbbi sarf malzemelerinin envanterini ABC, VED ve ABC–VED matris yöntemleri kullanarak değerlendirmeyi ve stok kontrolünün optimize edilmesine yönelik stratejiler geliştirmeyi amaçlamaktadır.

Yöntem: Araştırma, 2024 yılında Kırklareli ilinde bulunan A2 tipi bir acil sağlık hizmetleri istasyonunda yürütülmüştür. Toplam 131 kaleme ait yıllık tüketim ve maliyet verileri otomasyon kayıtlarından elde edilmiştir. Malzemelerin kritik düzeyleri (Hayati, Gerekli, İsteğe Bağlı), sekiz deneyimli sağlık ve idari personel ile gerçekleştirilen yapılandırılmış görüşmeler yoluyla belirlenmiştir. Stok kontrolünde yüksek, orta ve düşük öncelikli grupların tanımlanması amacıyla birleşik ABC–VED matrisi kullanılmıştır.

Bulgular: ABC analizi, kalemlerin %12,21'inin (A kategorisi) toplam harcamaların %69,32'sini oluşturduğunu göstermiştir. VED analizine göre hayati nitelikteki malzemeler stokların %55,73'ünü ve maliyetlerin %57,18'ini kapsamaktadır. Birleşik ABC–VED matrisi sonuçları, yalnızca 33 kalemden oluşan yüksek öncelikli grubun (AV, AE, BV) toplam harcamaların %73,15'ini tükettiğini ortaya koymuş; bu durum söz konusu malzemelerin klinik ve finansal açıdan kritik önemini vurgulamıştır. Orta öncelikli malzemeler stokların %71'ini oluşturmasına karşın maliyet etkileri sınırlı kalmış, düşük öncelikli malzemeler ise sayıca az olmalarına rağmen toplam maliyetlerin %10,3'ünü temsil etmiştir.

Sonuç: Acil sağlık hizmetleri, kendine özgü lojistik ve klinik gereksinimler doğrultusunda yapılandırılmış envanter yönetim stratejilerine ihtiyaç duymaktadır. ABC–VED modeli, maliyet etkinliği ile klinik gereklilikler arasında denge kurmaya olanak tanıyan bütüncül bir çerçeve sunmakta ve yaşam kurtarıcı malzemelerin kesintisiz erişilebilirliğini desteklemektedir. Matris temelli stok yönetim protokollerinin bölgesel ve ulusal acil sağlık hizmetleri lojistik sistemlerine entegrasyonu, hizmet etkinliğini, hazırlık düzeyini ve hasta sonuçlarını iyileştirebilir.

Anahtar Kelimeler: Acil sağlık hizmetleri, Envanter yönetimi, ABC analizi, VED analizi, ABC–VED matrisi

Healthcare provision is a critical sector directly linked to human life and must be continuously available. Within this framework, inventory management represents a fundamental function that influences operational efficiency, financial sustainability, patient safety, and treatment quality. In healthcare delivery, inventory processes aim to maintain stock levels that ensure uninterrupted supply while minimizing procurement and holding costs [1].

The financial burden of inadequate inventory control is substantial. In the United States, the annual cost of disposable hospital supplies alone is approximately $83 billion, with nearly $25.4 billion wasted each year due to inefficient supply systems [2]. These figures underscore that inventory management constitutes both a critical cost element and a key operational domain in healthcare organizations.

Inventory management, as a component of supply chain management, involves estimating material requirements, determining order quantities and frequencies, and maintaining safety stock levels [3]. Hospitals usually have stock in multiple locations, including warehouses, pharmacies, operating theatres, supply rooms and sterilisation departments. Standardised software systems and effective data segmentation can reduce costs and improve efficiency in these areas [4]. Stock imbalances, whether shortages or surpluses, threaten continuity of care and may lead to adverse patient outcomes, resource waste, and financial losses [5].

Emergency care services occupy a particularly vital role in healthcare systems, providing immediate interventions that directly affect survival and recovery. Response time in emergency departments is a crucial determinant of pre-hospital care outcomes[6]. However, common operational challenges remain, such as overcrowding, inadequate bed capacity, prolonged length of stay and suboptimal resource allocation. Ensuring adequate stock control and the appropriate allocation of supplies is therefore essential to guarantee timely interventions and maintain the quality of emergency care [7].

In Türkiye, emergency health services are organized through a legal and institutional framework that defines "A," "B," and "C" type stations. "A" type stations operate 24/7 with multiple crews and ambulances; "A1" stations include physicians, while "A2" stations do not. "B" type stations operate in conjunction with hospitals ("B1") or primary care facilities ("B2"), while "C" type stations provide ambulance services during limited hours as required [8]. Inventory management processes vary accordingly: A1, A2, and temporary C stations procure supplies directly from Provincial Ambulance Service warehouses and maintain sub-depots for ambulance needs, whereas B1 and B2 stations obtain supplies through the stock systems of their affiliated institutions.

The present study aims to analyze the stocks of medicines and medical supplies in emergency health service stations affiliated with the Chief Physician of a Provincial Ambulance Service in the Thrace Region of Türkiye, using the ABC, VED, and ABC–VED matrix methods. The objective is to provide recommendations for improving stock control practices in emergency stations.

Method

2.1. Study Design

This study was conducted at emergency health service stations affiliated with the Chief Physician of the Provincial Ambulance Service in Kırklareli province, located in the Thrace region of Türkiye. It was designed as a descriptive, cross-sectional, case-based inventory analysis. The analysis focused on a single A2-type Emergency Health Services Station, which was intentionally selected as the most active station in the city in terms of service volume, thereby providing a realistic representation of inventory dynamics in high-demand prehospital emergency settings. Annual stocks of medicines and disposable medical supplies used in 2024 were evaluated using ABC, VED, and ABC–VED matrix methods from an operational and managerial perspective rather than for the assessment of clinical outcomes. In Kırklareli, there are 25 emergency health stations, including 3 B1-type, 2 A1-type, and 20 A2-type units. In the absence of a physician, team leaders function as paramedics; however, neither paramedics nor emergency medical technicians (EMTs) are authorized to diagnose or prescribe independently. Preventive measures and preliminary assessments may be performed, while medication administration is limited to designated physicians within the 112 Emergency Services and requires prior approval from the on-call physician.

The study was conducted in three stages.

Stage 1: Data for the ABC analysis, including quantities and costs of medical supplies, were obtained from automation records maintained by depot authorities.

Stage 2: Data for the VED classification were collected through structured interviews with eight experienced professionals (physicians, paramedics, emergency medical technicians, managers, procurement officers, and pharmacy staff) affiliated with emergency health service stations or the Provincial Health Directorate. All participants had a minimum of two years of experience in either clinical practice or material management. In cases where discrepancies emerged among expert evaluations, the classification reflecting the highest level of criticality was adopted as the final assignment to minimize the risk of underestimating clinically vital materials. This approach ensured a conservative and safety-oriented classification strategy, consistent with inventory management practices recommended for emergency and critical care settings.

Stage 3: The combined ABC and VED results were used to construct the ABC–VED matrix, which was applied to evaluate and interpret the stock management practices at the emergency health service station.

2.2. Analysis

The analytical process was conducted sequentially. First, items were classified according to their annual consumption value using ABC analysis. Second, materials were categorized based on clinical criticality through VED analysis. Finally, both classifications were integrated to construct the ABC–VED matrix, allowing simultaneous evaluation of financial impact and clinical priority. This study employed ABC, VED, and ABC–VED matrix methods for stock control analysis. Data required for the analyses were processed using MS Excel.

The ABC method is based on the Pareto principle, which posits that a small proportion of items account for the majority of costs. In this system, "A" items (making up around 10% of the total materials) account for around 70% of the budget, making them the most costly items. "B" items (~20%) account for roughly 20% of expenditure, while the remaining "C" items (~70%) consume only about 10% of resources [9,10].

The VED method classifies items according to criticality into three groups: Vital (V), Essential (E), and Desirable (D). Vital items are indispensable for patient survival and uninterrupted care; essential items are necessary for effective hospital functioning of hospital; and desirable items are useful but not critical for patient safety or service continuity [11,12].

To enhance prioritization, the ABC and VED classifications were combined into a 3×3 matrix. Cross-tabulation yielded nine subgroups (e.g., AV, AE, CV), which were further consolidated into three categories [13]:

Category I (High Priority): AV, AE, BV items—high cost and/or high criticality, requiring strict control.

Category II (Moderate Priority): BE, CE, CV items—moderate in cost or importance, requiring routine monitoring.

Category III (Low Priority): BD, CD, AD items—low cost and low criticality, requiring minimal oversight.

The analysis covered 131 items used in 2024 at the A2-type emergency medical services station, comprising 43 medicines/serums and 88 disposable consumables. Items with different dosage forms or size variants were treated as separate entities to ensure accurate VED classification.

Results

This section summarizes the outcomes of the ABC, VED, and combined ABC–VED analyses of pharmaceuticals and disposable medical supplies used in a Type A2 emergency health services station during 2024. A total of 131 distinct items were evaluated, comprising both medications and single-use consumables.

The results are presented in three parts. Firstly, the ABC analysis shows how items are distributed according to their share of total expenditure. Secondly, the VED analysis classifies items by clinical criticality. Finally, the combined ABC–VED matrix identifies high-priority items requiring the most stringent inventory control. Each analysis is supported by tabular summaries that highlight the operational implications for emergency service management.

Table 1 presents the ABC classification of inventory items according to their relative contribution to total costs.

Table 1 summarizes the ABC analysis of 131 medical items used in 2024 at a Type A2 emergency health services station. The items were classified according to their proportional contribution to annual expenditure, revealing a significant imbalance between item volume and financial burden.

Category A comprised 16 items (12.21%) but accounted for 69,976.84 TL (69.32% of costs), indicating that a small subset of high-value supplies dominates overall expenditure. These items, mainly critical drugs and materials, are indispensable for emergency interventions.

Table 1. Material Numbers, Expenditure Amounts, And Percentages According to ABC Analysis

ABC	Material Number	Material Rate (%)	Expenditure Amount (TL)	Expenditure Rate (%)
A	16	12,21	69.976,84	69,32
B	29	22,14	20.268,43	20,08
C	86	65,65	10.701,58	10,60
Total	**131**	**100,00**	**100.946,86**	**100,00**

Category B included 29 items (22.14%) with a total cost of 20,268.43 TL (20.08%). While less financially dominant than Category A, these items support operational continuity and are frequently used in routine care.

Category C encompassed 86 items (65.65%), yet contributed only 10,701.58 TL (10.60%). Despite their low financial weight, the large number of items in this group poses logistical challenges for storage, tracking, and replenishment.

Building on the cost-based ABC classification, Table 2 presents the VED analysis, which categorizes items by functional importance (Vital, Essential, Desirable). This approach is particularly relevant in emergency care, where timely access to life-saving supplies is critical to patient outcomes.

Table 2 shows the VED classification of 131 items. Vital (V) supplies comprised 73 items (55.73%) with an expenditure of 57,725.39 TL (57.18%), underscoring the strong clinical dependence on life-saving materials in prehospital emergency care. Essential (E) category included 53 products (40.46%) accounting for 32,825.24 TL (32.52%) of the total costs, reflecting their importance in sustaining routine emergency operations. Desirable (D) items formed the smallest group (n=5; 3.82%) but accounted for 10,396.23 TL (10.30%), indicating that even non-critical materials can impose notable financial burdens when unit prices or procurement volumes are high.

Table 2. Material Numbers, Expenditure Amounts, And Percentages According to VED Analysis

VED	Material Number	Material Rate (%)	Expenditure Amount (TL)	Expenditure Rate (%)
V	73	55,73	57.725,39	57,18
E	53	40,46	32.825,24	32,52
D	5	3,82	10.396,23	10,30
Total	**131**	**100,00**	**100.946,86**	**100,00**

Table 3. Material Numbers, Expenditure Amounts, And Percentages According to ABC-VED Matrix Analysis

ABC- VED	V			E			D			Total		
	Amount	Expenditure Amount (TL)	Expenditure Rate (%)	Amount	Expenditure Amount (TL)	Expenditure Rate (%)	Amount	Expenditure Amount (TL)	Expenditure Rate (%)	Amount	Expenditure Amount (TL)	Expenditure Rate (%)
A	9	39.008,85	38,64	5	21.751,59	21,55	2	9.216,40	9,13	**16**	**69.976,84**	**69,32**
B	19	13.092,07	12,97	9	6.156,36	6,10	1	1.020,00	1,01	**29**	**20.268,43**	**20,08**
C	45	5.624,47	5,57	39	4.917,29	4,87	2	159,83	0,16	**86**	**10.701,58**	**10,60**
Total	**73**	**57.725,39**	**57,18**	**53**	**32.825,24**	**32,52**	**5**	**10.396,23**	**10,30**	**131**	**100.946,86**	**100,00**

Table 3 presents the combined ABC–VED matrix, which integrates cost- and criticality-based classifications. The 131 items were distributed across nine subgroups (e.g., AV, AE, BV) and consolidated into three priority categories:

High Priority: AV, AE, BV items, representing critical and/or costly supplies requiring strict control.

Medium Priority: BE, CE, CV items, requiring routine monitoring.

Low Priority: BD, CD, AD items, involving limited cost and clinical importance.

High-Priority Control Group (AV, AE, BV): This group contained 33 items and accounted for 73.15% of total expenditure, underscoring the financial and clinical concentration of emergency service inventories.

AV items (n=9) represented 38.64% of costs (39,008.85 TL), including high-cost, life-saving materials such as AMBU bags, intraosseous sets, intravenous cannulas, and diagnostic tools (e.g., EKG electrodes, glucose test strips).

AE items (n=5) accounted for 21.55% of spending (21,751.59 TL), consisting mainly of gloves and antiseptic solutions essential for infection control.

BV items (n=19) represented 12.97% of costs (13,092.07 TL) and included essential yet moderately priced supplies such as airway devices, adrenaline ampoules, isotonic solutions and suction sets.

Together, these three subgroups comprise 33 items and represent a total of 73.15% of all expenditures, highlighting a narrow but strategically crucial segment of the inventory.

Medium-Priority Control Group (BE, CV, CE): This category included 93 items (71% of all inventory) but accounted for only 16.54% of expenditures, reflecting a high operational volume with limited financial impact.

BE items (n=9) represented 6.10% of costs and included essential items for routine care, infection control, and wound managemen, such as gloves, gauze and antiseptics.

CV items (n=45) accounted for 5.57% (5,624.47 TL), comprising low-cost but vital materials such as airway devices, intravenous cannulas, and emergency drugs used in life support and critical care.

CE items (n=39) contributed 4.87% (4,917.29 TL), mainly low-cost consumables such as masks, dressings, and injectables required for daily clinical practice.

Collectively, these three subgroups account for 93 items, or approximately 71% of total inventory items, but only 16.54% of total expenditure, reflecting a significant operational volume with limited financial impact.

Low-Priority Control Group (AD, BD, CD): Items in this group are both low in clinical priority and vary in cost. While limited in number, some still represent a notable portion of expenditure.

AD includes 2 items, totaling 9,216.40 TL (9.13%), representing high-cost but low-priority items.

BD includes 1 item, totaling 1,020.00 TL (1.01%).

CD includes 2 items, with an expenditure of 159.83 TL (0.16%).

Although there are only five items in this group, they account for 10.30% of total expenditure. This suggests that even low-priority materials may incur substantial costs due to unit price or procurement practices.

Overall, the ABC, VED, and integrated ABC–VED analyses revealed marked asymmetries in cost distribution and clinical priority. The high-priority group (AV, AE and BV) comprised just 33 items, yet accounted for an impressive 73.15% of expenditure. This emphasises the critical role these items play in life-saving interventions such as airway management, vascular access, resuscitation, infection control and rapid diagnostics. In contrast, the medium-priority group (BE, CV, CE) comprised 93 items with a modest cost share (16.54%) but remained essential for sustaining daily operations. Despite low unit costs, their high consumption volume reinforces their importance for workflow continuity and patient safety. These findings provide an empirical foundation for refining inventory strategies, which are further addressed in the discussion.

Discussion

This study highlights that inventory management in emergency health stations requires a more sensitive and strategic approach than in hospitals or the pharmaceutical sector. The predominance of Group A and Group V items underscores the need to secure the continuous availability of a limited set of high-value, life-saving supplies. In particular, AV items, which represent nearly 40% of expenditures, concentrate both financial and operational risks. In the context of time-critical emergency care, even short-term shortages of AV or BV items may directly compromise patient survival, emphasizing the need for dynamic, priority-based stock control and automated tracking systems tailored to emergency services.

The ABC analysis showed that 12.21% of items accounted for 69.32% of costs, consistent with findings in military hospitals in India (70.03%) [14], Turkish private hospital emergency departments (69.29%) [15], and Indonesian public hospitals (70.84%) [16]. This pattern, reflecting the Pareto principle, confirms the importance of targeted resource allocation [9,10].

The VED analysis revealed that vital items comprised 55.73% of inventory and 57.18% of costs, comparable with Indian (50.9%) hospitals [17]. Although limited in number, vital items carry disproportionate clinical importance, particularly in emergency care where dependence on life-saving materials is inevitable [18].

The ABC–VED matrix demonstrated that Category I (AV, AE, BV) included 25.19% of items but consumed 73.15% of costs. Similar concentrations were observed in Turkish hospitals [19,20] and Indian teaching hospitals [17], reaffirming the need for rigorous monitoring of high-cost, high-priority items [21]. In contrast, medium-priority groups (CE, CV, BE) comprised the majority of items but had limited financial impact, while low-priority categories (CD, BD, AD) contributed only 10.3% of spending. Nevertheless, their volume creates logistical demands, which reinforcing earlier evidence of the operational complexity of healthcare supply chains [22].

These findings support the growing consensus that ABC analysis alone is insufficient in emergency and critical care. Integrating VED with ABC provides a dual perspective, balancing economic efficiency with clinical necessity [23,24]. Low-cost but vital items such as adrenaline ampoules illustrate the limitations of cost-only approaches. This study contributes to the literature by addressing pre-hospital emergency services, which face logistical and clinical challenges distinct from hospital settings.

Recent studies underline that inventory management in time-critical service settings requires a balance between cost efficiency and operational resilience rather than strict inventory minimization. Empirical evidence suggests that overly lean inventory structures may expose organizations to service disruptions, particularly in environments characterized by high uncertainty and immediate response requirements [25]. In this respect, multi-criteria classification approaches such as the ABC–VED matrix have been increasingly emphasized as pragmatic tools that integrate financial importance with clinical criticality, especially where real-time automation is limited [26]. Recent work further demonstrates that integrating ABC–VED with multi-criteria decision analysis can improve the prioritization and availability of critical medical items while reducing overall inventory costs in healthcare contexts with constrained infrastructure [27]. The present study aligns with this emerging evidence by demonstrating that conservative, safety-oriented inventory classification remains a valid and defensible strategy for pre-hospital emergency services operating under resource and infrastructure constraints.

Several limitations must be noted. The study was confined to a single region and excluded other station types, limiting generalizability. Furthermore, the lack of automation infrastructure restricted data accuracy. Future multi-center studies incorporating automated tracking systems could provide stronger evidence for broader application.

In conclusion, aligning inventory strategies with both financial and clinical priorities is essential in emergency health services. The ABC–VED model enables managers to optimize resources, safeguard timely access to critical supplies, and improve patient outcomes. From a policy perspective, implementing differentiated protocols at the emergency station level—such as region-specific procurement algorithms, safety stock thresholds for AV and BV items, and integration of EMS inventories into national logistics systems—may enhance efficiency and readiness in pre-hospital care.

Conclusion

The study's findings reveal the necessity for healthcare institutions to adopt an integrated approach to stock management that considers both cost-effectiveness and clinical priorities.

This study contributes a unique perspective to the field of healthcare inventory management by applying ABC, VED, and ABC-VED matrix analyses within the context of emergency health service stations—an area that remains largely underexplored in existing literature. While previous research has predominantly focused on hospital settings and the pharmaceutical industry [28-30], this study addresses the critical and time-sensitive nature of inventory management in emergency stations, where rapid access to essential medical supplies directly impacts patient outcomes. By highlighting the operational realities of an A2-type Emergency Health Services Station, the research underscores the necessity of developing tailored inventory strategies that reflect the urgency and unpredictability of emergency medical interventions.

A notable strength of this study lies in its practical relevance and potential to inform healthcare logistics policy and emergency preparedness protocols. However, its primary limitation is the geographical scope, as the study was conducted in a single province within the Thrace region of Türkiye. While the findings provide valuable insights, future research should expand to include diverse regions and station types to enhance generalizability and further validate the effectiveness of matrix-based stock control methods in emergency healthcare settings. The study did not account for potential external factors such as seasonal variations, emergency outbreaks, or supply chain disruptions that could have influenced inventory levels during the study period.

Declarations

Conflicts of Interest

The authors declare no conflicts of interest.

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Availability of Data and Materials

All data generated or analyzed during this study are included in this published article.

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Authors' contributions

All authors have read and approved the final version of the article.

Ethics Statement

The study protocol titled *"Analysis of Medical Material Stocks in Emergency Health Service Stations According to ABC, VED and ABC–VED Matrix Stock Control Methods"* was reviewed and approved by the Ethics Committee of Trakya University Faculty of Medicine (Approval No: 02/30, Date: January 20, 2025). The study did not involve human participants or animal subjects. The research was conducted in accordance with the principles of the Helsinki Declaration.

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