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Development of Drug Plan and Control App Using ABC, VEN, and Combined Methods for Inventory Control

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ABSTRACT

Drug Plan and Control (Drug PC) application is a web-based digital tool designed to support pharmaceutical management in healthcare facilities by assisting in the planning, monitoring, and control of drug inventories. This study aimed to enhance the Drug PC (Plan and Control) application by integrating a drug categorization feature to improve pharmaceutical inventory control. Efficient inventory management is critical in healthcare, as poor control can lead to shortages, overstocking, and financial inefficiencies. The application was developed using PHP as the programming language and MySQL as the database management system. Drug categorization was performed using the ABC method, the VEN method, and a combination of both (ABC-VEN matrix). To evaluate the application's performance, Blackbox testing was conducted to assess the functionality of the user interface. In addition, manual calculations using Microsoft Excel were performed to validate and compare the application results with drug inventory data from two hospitals. Ethical approval was obtained from the Health Research Ethics Committee of the Faculty of Medicine, Tadulako University. The results demonstrated successful integration and 100% functionality accuracy of the new features. Categorization outputs aligned fully with manual data. Hospital 1 followed a typical ABC distribution (70:20:10%), while Hospital 2 showed deviations. VEN classification revealed a significantly higher proportion of Vital (V) drugs in Hospital 1 compared to Hospital 2 ($p < 0.05$). Combined ABC-VEN results showed CE (C + Essential) as the most common group. High-cost drugs (Category I) represented the majority of investment in both hospitals. In conclusion, the study shows that integrating categorization methods into digital tools like Drug PC can enhance drug inventory control, improve procurement planning, and optimize healthcare resource allocation.

Key Messages:

- Integrating ABC, VEN, and combined ABC-VEN methods into the Drug PC application significantly improves pharmaceutical inventory control by enabling data-driven, prioritized decision-making in drug procurement and stock management.
- The newly developed categorization feature demonstrated high accuracy and consistency with manual records, highlighting its potential to enhance efficiency, reduce costs, and address drug supply challenges in healthcare facilities.

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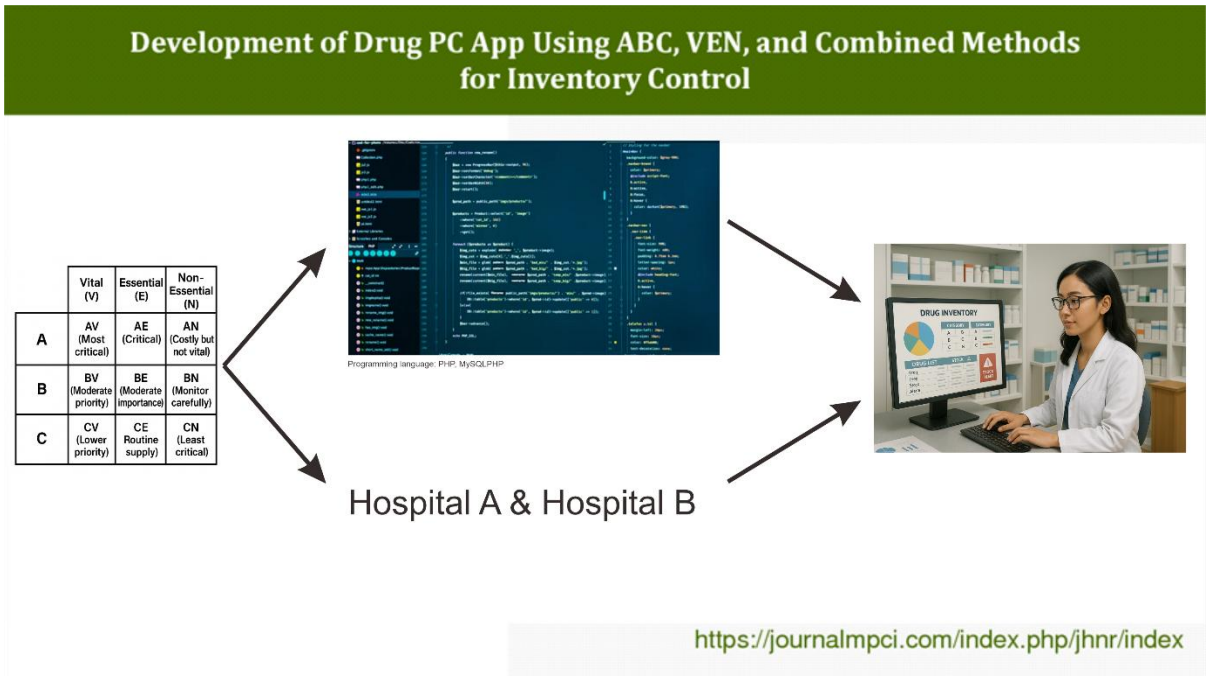
GRAPHICAL ABSTRACT



INTRODUCTION

Pharmaceutical inventory control is an essential activity aimed at ensuring that the desired objectives are achieved through established strategies and programs, thereby preventing problems such as overstocking or stockouts in pharmaceutical facilities (1). Inventory control is carried out in pharmaceutical facilities, such as hospitals, which are expected to provide high-quality healthcare services to the public, including in the pharmaceutical sector. As emphasized in Law of Ministry of Health of Republic of Indonesia No. 72 of 2016 regarding pharmaceutical service standards in hospitals, pharmaceutical services must align with patient care, ensuring the availability of quality medications at prices accessible to the general public (2).

According to Baybo et al. (2022), inventory control refers to the activities that ensure the availability of goods in the appropriate types and quantities at the right place and time while maintaining a balance between the benefits of inventory and the costs incurred (1). Inventory refers to the stock of goods available or stored in warehouses, which will be processed or distributed to meet specific objectives. Inventory must be controlled and planned to determine how much stock should be ordered economically, how much safety stock is necessary, and when to reorder to ensure inventory availability, thus improving efficiency (3). Inventory is essential for addressing uncertainties in demand, supply shortages, and wait times for ordered goods. Excessive or insufficient inventory can lead to losses for an organization or hospital. Excessive inventory burdens hospitals with high storage costs, while insufficient inventory prevents hospitals from benefiting from sales and impacts service delivery to patients (4).

Stockouts of medications in healthcare units represent a complex issue, requiring effective and efficient drug management to ensure the availability of medications in the correct types and quantities according to demand (5). Effective pharmaceutical inventory management can reduce supply costs without compromising stock levels. This can be achieved through proper logistics management, including planning, procurement, storage, distribution, and supply chain management (6).

One effective inventory control method is the categorization of drugs using the ABC (Always Better Control), VEN (Vital, Essential, Non-Essential), and ABC-VEN Combined methods. The ABC-VEN matrix has been widely utilized by researchers to classify inventory items based on investment value and the characteristics of pharmaceutical supplies. Moreover, it helps identify the overall cost efficiency of inventory management after applying the ABC-VEN categorization, compared to the current financing methods (7).

Information systems are organizational systems that meet the daily transaction processing needs

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of an organization while supporting managerial functions and strategic activities, providing necessary information for decision-making (8).

The Drug PC (Plan and Control) is a web-based pharmaceutical management information system designed and developed in 2023. It serves as a tool for pharmacy personnel in healthcare facilities to manage pharmaceutical inventories. Initially, the Drug PC application was intended for pharmaceutical planning and inventory control, offering several features to aid pharmacy staff in planning medication for each period and overseeing pharmaceutical supplies. The features of the Drug PC include: a Database Feature, Medication Planning Features (using the Consumption Method, Epidemiological Method, and Combined Method), and Inventory Control Features (using the EOQ Method and ROP Method). As part of its ongoing development, the Drug PC application will include a drug categorization feature that classifies drugs based on the ABC, VEN, and combined ABC-VEN methods. This feature is expected to greatly assist users in planning and procuring medications according to available budgets and the urgency of each drug category (9).

Pharmacy staff working in healthcare settings such as hospitals, pharmacies, and clinics often lack tools for categorizing drugs based on budget alignment and the essential nature of medications needed by patients. As a result, the planning and procurement processes may be less effective and efficient. This can affect the revenue of the healthcare facility and the satisfaction of users of pharmaceutical supplies, including healthcare professionals (doctors, nurses, midwives) and patients. The use of the Drug PC information system, with its planning and inventory control features, especially the drug categorization based on ABC, VEN, and combined methods, will significantly enhance the work of pharmaceutical personnel and, more broadly, contribute to the development of knowledge and technology in the pharmaceutical field.

The development of the Drug PC application with the addition of drug categorization features based on the ABC, VEN, and ABC-VEN combined methods is grounded in research demonstrating the effectiveness and efficiency of these methods. The ABC and VEN systems offer valuable recommendations for decision-makers in drug procurement based on the ABC and CEN matrices (10). Analysis of ABC Investment and ABC Usage has led to policy recommendations for hospitals, such as in the study conducted at RS Awal Bros Batam, to improve pharmaceutical inventory control and address stockout issues (4). A study at RS Bhayangkara Kediri showed that the use of the ABC and VEN methods to control medication for BPJS Health patients improved the effectiveness and efficiency of drug management, especially in the AE category (11). Pharmaceutical supply planning using the ABC-VEN and EOQ methods has been shown to offer better cost efficiency (7). The ABC-VEN technique must be implemented to ensure efficient use of resources and eliminate waste and stockouts in mid-level healthcare service facilities (12). This study aimed to evaluate the effectiveness of drug inventory control using ABC, VEN, and the ABC-VEN matrix categorization, identify the most critical and high-cost drug categories for prioritized management, propose inventory management strategies based on the combined categorization results, and conduct blackbox testing on the developed Drug PC application to assess its functionality and ensure it meets user requirements without examining internal code structure.

METHODS

Research Design

This study employed a quantitative applied research approach within the framework of systems development. It followed the System Development Life Cycle (SDLC) methodology to design and implement the Drug PC application. Data collection involved user feedback through black-box testing and validation of system output by comparing application-generated results with manual calculations using Microsoft Excel. Quantitative analysis was used to assess the accuracy and functionality of the drug categorization features.

Population and Sample

The two hospitals were selected based on their differing operational scales and their representation of common inventory management challenges in regional healthcare settings. Bhayangkara hospital is in Palu City and Torabelo Hospital is in Sigi Regency. Both The hospital represents Type C hospitals. Additionally, existing collaborations facilitated access to relevant data and system validation. In

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addition, the sample included pharmaceutical inventory data from the same two hospitals, used to validate the categorization features (ABC, VEN, and ABC-VEN) of the application. This data included information on drug names, unit prices, and historical usage volumes, collected through observation sheets and imported into the application for analysis. The user population in this study comprises healthcare professionals and pharmacy staff involved in pharmaceutical inventory management within hospital settings. The sample included a selected group of users, pharmacy personnel from two hospitals located in Palu and Sigi, Central Sulawesi, who participated in the testing of the Drug PC application. The users who participated in the Blackbox testing were pharmacists familiar with the hospital's drug information system.

Research Location

This study was conducted in two healthcare facilities located in Central Sulawesi, Indonesia. These hospitals were selected because they are reference hospitals with available pharmaceutical inventory data suitable for comparison, application testing, and validation of the Drug PC system, using actual inventory records and feedback from pharmacy personnel.

Instrumentation or Tools

The primary instrument used in this study was the Drug PC application, which was developed using PHP as the programming language and MySQL as the database management system. The application includes a drug categorization feature based on the ABC, VEN, and ABC-VEN methods. Additional tools and instruments included: 1) Microsoft Excel, used for manual calculations of drug categorization to validate the application's output; 2) Observation sheets (in Excel format), used to collect pharmaceutical inventory data, including drug names, unit prices, and usage volumes; 3) Questionnaires, used during black-box testing to gather user feedback on the application's usability, interface, and functional performance.

Data Collection Procedures

Data collection in this study was conducted in two phases: system validation and user testing.

1. Pharmaceutical Inventory Data Collection

Pharmaceutical data were collected from two hospitals located in Palu and Sigi, Central Sulawesi. The data included the names of drugs, unit prices, and usage quantities from the previous period. These data were obtained through observation sheets in Microsoft Excel format, which were completed by the pharmacy departments at each hospital. The collected data were then imported into the Drug PC application to test the categorization features (ABC, VEN, and ABC-VEN) and generate drug classification outputs.

2. Manual Calculation for Validation

To validate the accuracy of the Drug PC application, the same inventory data were manually calculated using Microsoft Excel. The results were compared with the application's output to determine the level of consistency. A 100% match between the manual and automated outputs was used as the benchmark for feature success.

3. User Testing and Feedback Collection

Functionality testing of the application was conducted through black-box testing. Pharmacy personnel who were selected as respondents interacted with the Drug PC application and evaluated its performance. Feedback was collected using structured questionnaires, which included items on user interface, feature functionality, and ease of use. This process provided insight into user satisfaction and the practical reliability of the application in a real-world setting.

Data Analysis

Data analysis in this study was conducted using both quantitative comparison methods and descriptive statistical analysis, tailored to evaluate the functionality and accuracy of the Drug PC application.

1. Functional Accuracy Analysis

To assess the accuracy of the drug categorization feature, the application-generated outputs were compared with manually calculated results using Microsoft Excel. The analysis focused on three categorization methods: ABC, VEN, and ABC-VEN combination. A result was considered accurate if there was a 100% match between the application output and manual calculations. This comparison ensured that the algorithm implemented in the Drug PC application functioned correctly.

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2. Black-box Testing Analysis

User responses from black-box testing were analyzed descriptively. The questionnaires used to collect user feedback contained structured items that assessed the application's functionality, user interface, and ease of use. The results were tabulated to evaluate the consistency of system behavior with user expectations and to identify any functional discrepancies.

3. Descriptive Summary of Categorization Results

The results of the categorization features were also presented in tabular form, showing the distribution of drugs across ABC, VEN, and ABC-VEN categories. Percentages and frequency counts were calculated to describe the proportion of drugs falling into each classification group. These summaries provided insight into the composition of pharmaceutical inventory and helped demonstrate the utility of the application for inventory control.

CODE OF HEALTH ETHICS

This study received ethical clearance from the Health Research Ethics Committee of the Faculty of Medicine, with approval number 863/UN28.1.30/KL/2024, issued on July 23, 2024. All procedures involving human participants, specifically the participation of pharmacy staff in system testing and feedback collection, were conducted in accordance with ethical standards. Informed consent was obtained from all respondents prior to their involvement in the study, and data confidentiality was maintained throughout the research process. The confidentiality of all participants was strictly maintained throughout the research process.

Table 1. ABC, VEN, and combined ABC-VEN matrix

Matrix ABC	VEN Category			PUT Category
	V	E	N	
A	AV	AE	AN	P
B	BV	BE	BN	U
C	CV	CE	CN	T

Note: Group P = AV, AE, AN; Group U = BV, BE, BN; Group T = CV, CE, CN; Group I = AV, AE, AN, BV, CV; Group II = BE, BN, CE; Group III = CN

RESULTS

The drug categorization feature has been developed as an integral component of the web-based *Drug PC* application. This application is designed to assist pharmaceutical personnel in healthcare facilities with managing and controlling drug inventory.

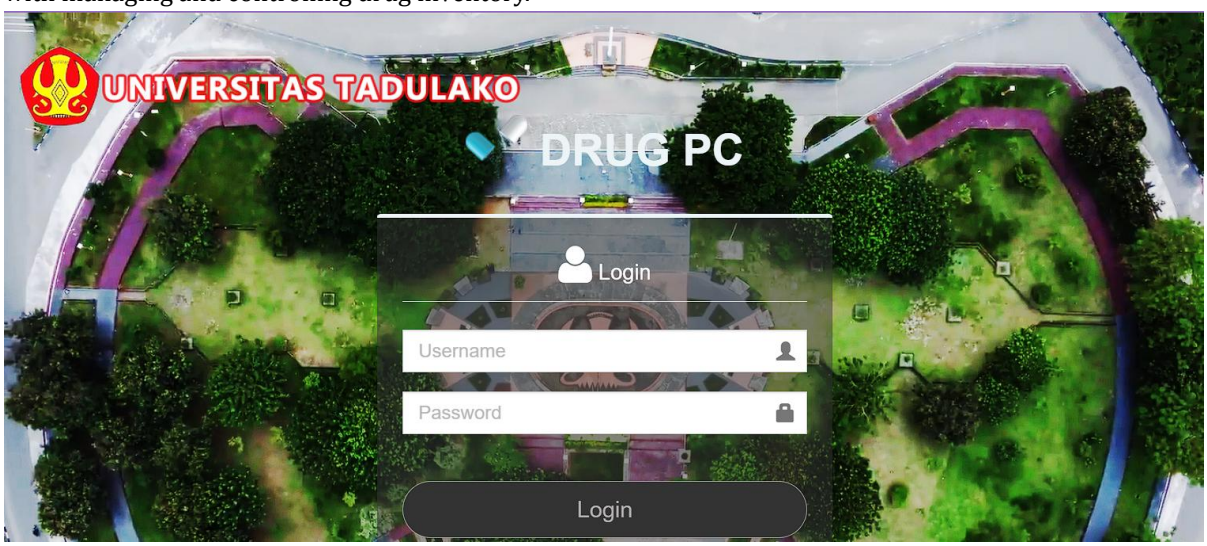

Figure 1. Web Interface of the Drug PC Information System (Drug Plan and Control)

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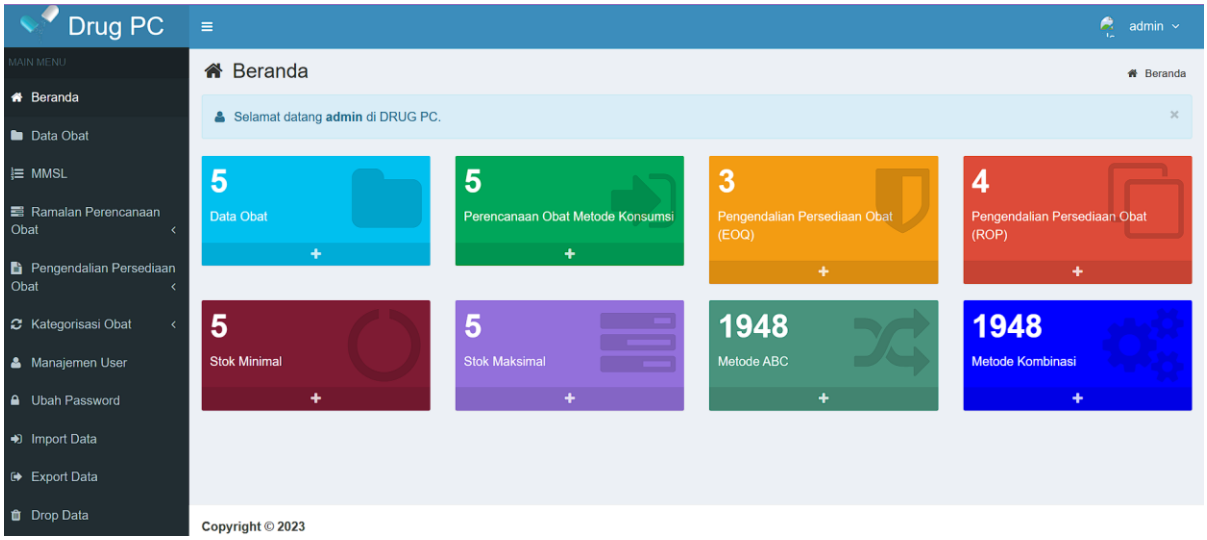

Figure 2. Dashboard View of the Drug PC Information System

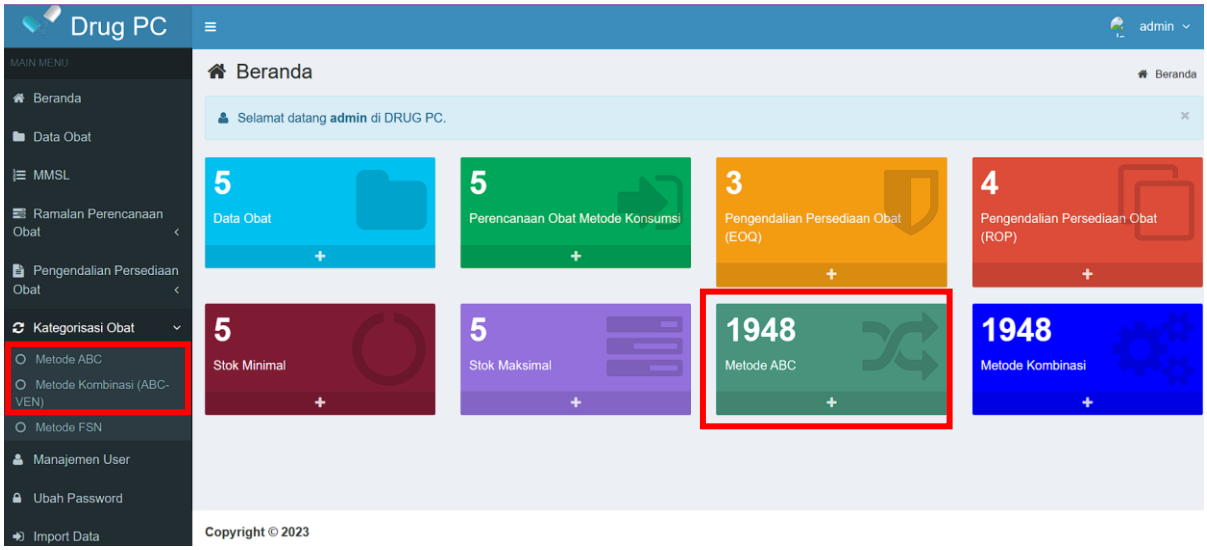

Figure 3. Application Dashboard of Drug PC

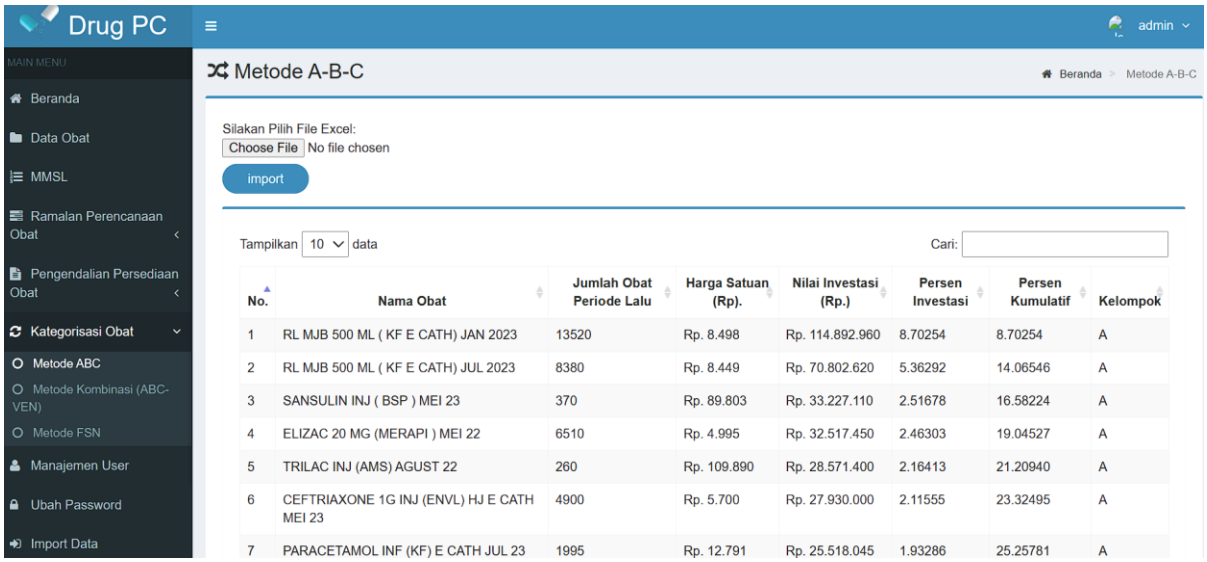

Figure 4. Interface of the ABC Method Feature

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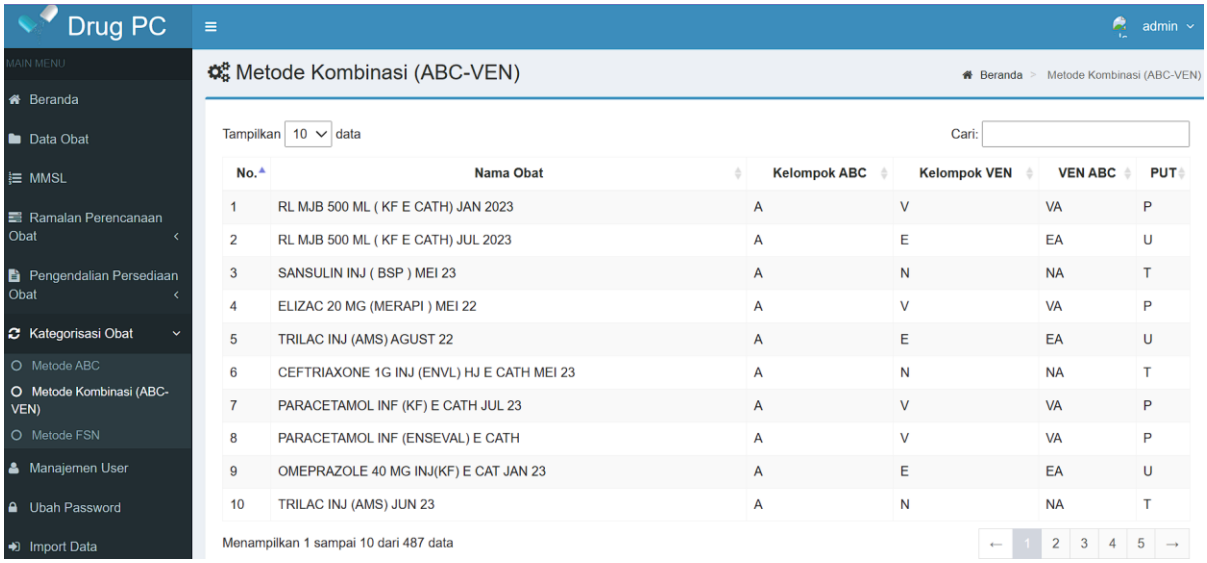

Figure 5. Interface of the VEN and ABC-VEN Combination Feature

Black box functionality testing was conducted to ensure that the software/application performs in accordance with the specified requirements and expected functionalities. This testing involves verifying whether all expected features are present and function correctly. In this study, the testing was carried out with a group of 10 respondents who used the categorization feature. The results of the test scenarios and expected outcomes are presented in the following table 2.

Table 2. Test Scenarios and Expected Results in Black Box Testing

No.	Test Field	Test Scenario	Expected Result
1	**App Link**	Typing "drugpc.com" in Google search	The login interface will appear.
2	**Log In**	Entering "admin" as both username and password, then clicking login	enter the main dashboard
		Entering other words in the username and password fields, then clicking login	A message will appear: "Login failed! Please check your Username and Password."
		Leaving the username and password fields empty	A warning will appear prompting the user to fill in the fields.
3	**Drug Categorization Menu**	Clicking the "Drug Categorization" menu on the left sidebar	Two submenus will appear (ABC Method and Combined Method (ABC-VEN))
4	**ABC Method Feature**	Clicking the "ABC Method" menu	The ABC Method page will appear
		Clicking the "Choose File" icon to upload an Excel file	Will open the computer/laptop file directory.
		Selecting a pre-filled Excel file in the correct format	Will return to the ABC Method page.
		Clicking the "Import" icon	A message will appear: "Successfully Imported."
		Clicking the "OK" icon on the successful import page	Will return to the ABC Method page showing populated data: number, drug name, previous period quantity, unit price, investment value, investment percentage, cumulative percentage, and group.
		Selecting the "Export Excel" icon on the ABC Method page	An Excel file will be downloaded.
		Clicking "Import" without selecting an Excel file	A warning will appear to select an Excel file.
		Clicking "Choose File" and selecting an incorrect format Excel file, then importing	A message will appear: "Successfully Imported."
		Clicking "OK" on the successful import page	Will return to the ABC Method page, but the displayed data will be incorrect.
		Clicking "Choose File" and selecting a	Will return to the ABC Method page with

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No.	Test Field	Test Scenario	Expected Result
		non-Excel file, then importing	an incorrect output/display.
5	**Combined Method (ABC-VEN) Feature**	Clicking the "Combined Method (ABC-VEN)" menu on the sidebar	The Combined Method (ABC-VEN) page will appear.
		Drug data is input from the ABC Method page by selecting the "Choose File" icon to upload an Excel file	Will open the computer/laptop file directory.
		Selecting an Excel file that includes VEN data in the correct format	Will return to the ABC Method page.
		Clicking the "Import" icon	A message will appear: "Successfully Imported."
		Clicking "OK" on the successful import page	Will return to the ABC Method page.
		Returning to the Combined Method (ABC-VEN) page	The page will display data input: number, drug name, ABC group, VEN group, ABC-VEN group, and PUT.
		Selecting the "Export Excel" icon on the Combined Method page	An Excel file will be downloaded.
		Uploading an Excel file without VEN data and clicking "Import"	The Combined Method page will display data without the VEN group.
		Selecting the "Export Excel" icon on the Combined Method page	An Excel file will be downloaded.

Table 3. Results of Functionality Testing

No.	Item Tested	Sum of Item	% accuracy	Percentage
1	Link Aplikasi	1	100%	Compliant
2	Login	3	100%	Compliant
3	Drug Categorization Menu	1	100%	Compliant
4	ABC Method Feature	10	100%	Compliant
5	Combined Method (ABC-VEN) Feature	9	100%	Compliant
	Total	24	100%	Compliant

The output accuracy test was conducted by comparing the results of ABC, VEN, and Combined (ABC-VEN) drug categorization performed manually using Microsoft Excel with those generated by the *Drug PC* application. This test aimed to ensure that the drug categorization feature within the application produces results consistent with manual calculations, thereby validating the accuracy and reliability of the application's output. To perform the test, a simulation dataset of 100 drug items was used, each with assigned unit prices and usage quantities. The results of this comparison are presented in Table 4.

Table 4. Accuracy of Application Output Compared to Manual Calculation

Result from Drug PC app			Result from Ms. Excel			Status
Method	**Drug Category**	**Sum (n=100)**	**Method**	**Drug Category**	**Sum (n=100)**	
ABC	A	18	Metode ABC	A	18	compliant
	B	28		B	28	compliant
	C	54		C	54	compliant
VEN	V	43	Metode VEN	V	43	compliant
	E	29		E	29	compliant
	N	28		N	28	compliant
Combination Method	VA	8	Combination Method	VA	8	compliant
	VB	12		VB	12	compliant
	VC	23		VC	23	compliant
	EA	5		EA	5	compliant
	EB	8		EB	8	compliant
	EC	16		EC	16	compliant

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Result from Drug PC app			Result from Ms. Excel			Status
Method	Drug Category	Sum (n=100)	Method	Drug Category	Sum (n=100)	
	NA	5		NA	5	compliant
	NB	8		NB	8	compliant
	NC	15		NC	15	compliant
	P	43		P	43	compliant
PUT	U	29	PUT	U	29	compliant
	T	28		T	28	compliant

H2 =IF(G2<75.01,"A",IF(G2<95.01,"B","C"))

No.	Nama Obat	Penggunaan Obat Periode Lalu (a)	Harga Satuan (Rp.) (b)	Nilai Investasi (Rp.) (c)= (a x b)	Persen Investasi (%) (d)=(c)/(Total Nilai Investasi)x100	Persen Kumulatif (%) (e)	Kelompok ABC	Kelompok VEN	Kombinasi	Kombinasi ABC-VEN (PUT)
1	Aqua Pro Injeksi 25 ml	6,885	2,860.00	19,691,100.00	8.41708	8.42	A	V	VA	P
2	Methylprednisolon inj 0,125 mg	1,473	11,449.00	16,864,377.00	7.20878	15.63	A	E	EA	U
3	Paracetamol infus	925	16,003.00	14,802,775.00	6.32754	21.95	A	N	NA	T
4	Meropenem injeksi 1 g	320	45,540.00	14,572,800.00	6.22923	28.18	A	V	VA	P
5	Cefotaxim Inj	3,135	4,410.00	13,825,350.00	5.90973	34.09	A	E	EA	U
6	Ranitidin injeksi	7,898	1,678.00	13,252,844.00	5.66501	39.76	A	N	NA	T
7	Piracetam inj 3 gr	1,204	7,700.00	9,270,800.00	3.96286	43.72	A	V	VA	P
8	Cefixime tab 100 mg	11,693	750.00	8,769,750.00	3.74868	47.47	A	V	VA	P
9	Kalsium Glukonat Inj	1,052	7,800.00	8,205,600.00	3.50753	50.98	A	E	EA	U
10	Ondansetron injeksi	6,364	1,254.00	7,980,456.00	3.41129	54.39	A	N	NA	T

Figure 6. Manual Calculation Using Microsoft Excel

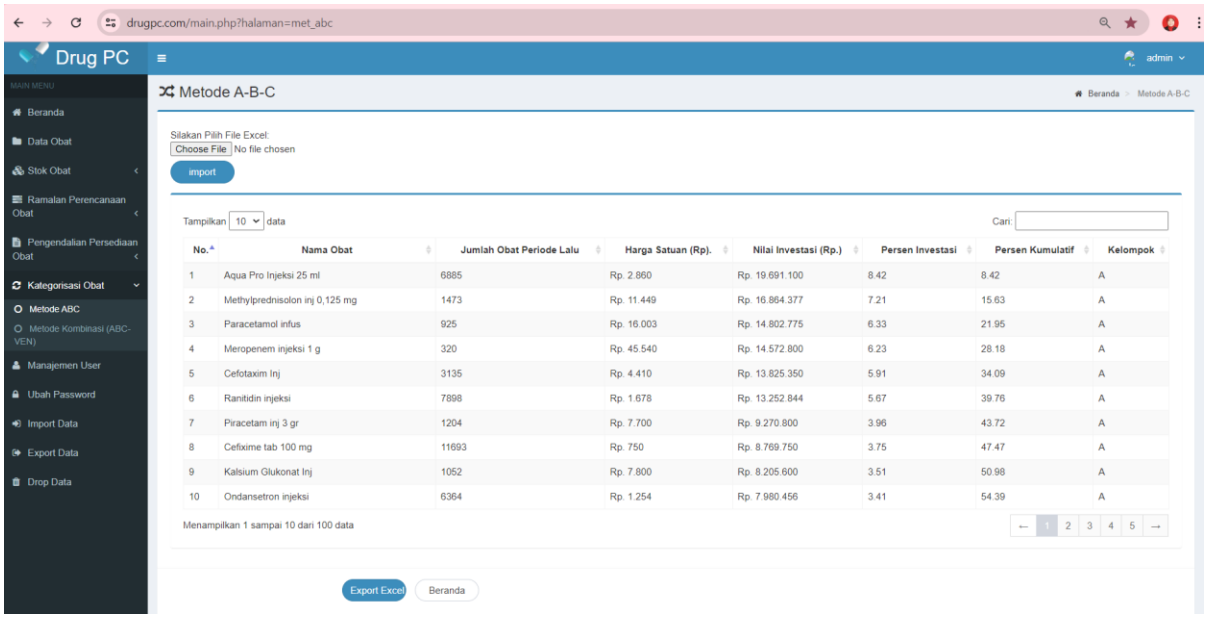

Figure 7. Drug Categorization Output from the Drug PC Application

The drug categorization feature was tested by generating ABC, VEN, and combined category groupings using drug inventory data provided by application users (respondents) from two different hospitals: Tora Belo Regional Public Hospital, Sigi (Sample 1), and Bhayangkara Hospital Level III, Palu (Sample 2). The results of the ABC categorization are presented in the table 5.

Table 5 shows how drugs were grouped using ABC, VEN, and ABC-VEN methods at two hospitals: Tora Belo Regional Public Hospital (Sample 1) and Bhayangkara Hospital Level III (Sample 2). In the ABC method, a small number of drugs (category A) made up most of the spending. At Sample 1, only 9.82% of drugs were in category A but used 65.87% of the total budget. At Sample 2, 19.71% of the drugs were in category A and used 74.99% of the budget. Categories B and C had more drugs but much lower spending.

Using the VEN method, most of the drugs in both hospitals were labeled as essential (E), making up over 70% of the items and around 85% of the cost. Vital (V) and non-essential (N) drugs made up a

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smaller portion.

When combining ABC and VEN methods, the AE group (high-cost and essential drugs) stood out. These drugs used the biggest part of the budget, 65.87% in Sample 1 and 68.14% in Sample 2, though they made up less than a fifth of the total drug items. This means AE drugs are the most important to manage carefully because they are both expensive and necessary.

Table 5. Drug Categorization Based on the ABC Method

Category		Sample 1		Sample 2	
		Sum and Item Percentage (n=326)	Value and Investation % (Rp.)	Sum and Item % (n=487)	Value and Investation % (Rp.)
ABC	**A**	32 (9.82 %)	377,936,233 (65.87 %)	96 (19.71 %)	989.983.638 (74.99 %)
	B	69 (21.17 %)	22,217,456 (3.87 %)	179 (36.76 %)	263.538.427 (19.96 %)
	C	225 (69.02 %)	4,817,471 (0.84 %)	212 (43.53 %)	66.701.922 (5.05 %)
VEN	**V**	55 (16.87 %)	55,882,336 (9.74 %)	31 (6.37 %)	38.202.974 (2.89 %)
	E	239 (73.31 %)	490,124,477 (85.42 %)	354 (72.69 %)	1.141.874.658 (86.49 %)
	N	32 (9.82 %)	27,768,211 (4.84 %)	102 (20.94 %)	140.146.355 (10.62 %)
ABC-VEN	**AV**	5 (1.53 %)	28,847,409 (5.03 %)	3 (0.62 %)	8.728.700 (0.66 %)
	BV	15 (4.60 %)	22,217,456 (3.87 %)	12 (2.46 %)	8.844.196 (0.67 %)
	CV	35 (10.74 %)	4,817,471 (0.84 %)	16 (3.29 %)	726.310 (0.06 %)
	AE	26 (7.98 %)	377,936,233 (65.87 %)	79 (16.22 %)	899.604.806 (68.14 %)
	BE	46 (14.11 %)	88,700,398 (15.46 %)	131 (26.90 %)	223.167.096 (16.90 %)
	CE	167 (51.23 %)	23,487,846 (4.09 %)	144 (29.57 %)	43.162.248 (3.27 %)
	AN	1 (0.31 %)	17,984,340 (3.13 %)	14 (2.87 %)	45.878.070 (3.47 %)
	BN	8 (2.45 %)	8,669,751 (1.51 %)	37 (7.60 %)	31.527.135 (2,39 %)
	CN	23 (7.06 %)	1,114,120 (0.19 %)	51 (10.47 %)	5.887.490 (0.45 %)
	P	55 (16.87 %)	14,206,330 (2.48 %)	31 (6.37 %)	38.202.974 (2.89 %)
	U	239 (73.31 %)	557,711,729 (97.20 %)	354 (72.69 %)	1.141.874.658 (86.49 %)
	T	32 (9,82 %)	1,856,966 (0,32 %)	102 (20.94 %)	140.146.355 (10.62 %)
	I	82 (25.15 %)	451,802,909 (78.74 %)	124 (25.46 %)	1.012.610.412 (76.70 %)
	II	221 (67.79 %)	120,857,995 (21.06 %)	312 (64.07%)	289.876.860 (21.96 %)
	III	23 (7.06 %)	1,114,120 (0.19 %)	51 (10.47 %)	17.736.715 (1.34 %)

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DISCUSSION

Design of the Drug Categorization Feature

The purpose of the categorization feature is to enable users to effectively monitor and regulate drug procurement and utilization based on the ABC and VEN classification methods. Additionally, the feature supports prioritization in procurement by identifying drugs that fall within the combined ABC-VEN matrix. The development of the *Drug PC* application includes the implementation of two new features: the ABC method drug categorization and the combined ABC-VEN categorization. The following is the display of the *Drug PC* application dashboard featuring the newly added functionalities.

Data Requirements and Implementation of Drug Categorization

To perform drug categorization, the required data include the previous period's drug usage quantities and the unit prices of each drug. These data are initially prepared using Microsoft Excel and subsequently imported into the application to generate output based on the ABC, VEN, and combined ABC-VEN classification methods. The use of this application is considered both user-friendly and efficient.

The implementation of the ABC categorization method within the *Drug PC* application was developed to facilitate more effective inventory control. The ABC-VEN analysis helps identify drug categories that require careful supervision and control due to cost considerations and the critical importance of certain medications (13). Inventory control strategies that incorporate the ABC-VEN method and its combination can significantly enhance pharmaceutical service delivery. These strategies not only promote efficient and effective use of limited financial resources but also help prevent drug shortages, including stock-outs (14).

Black Box Testing (Functionality Testing)

Black box testing focuses on evaluating the detailed aspects of the *Drug PC* application, including its user interface and the functionality of each page. This testing method does not involve examining the application's source code; rather, it emphasizes assessing the program's behavior and output based on its intended functions. Consequently, the primary focus of this test lies in verifying the accuracy of information displayed and the functionality embedded within each component of the application (15).

The black box testing process is entirely conducted from the user's perspective. It plays a crucial role in the software testing phase, as it helps validate the system's functionality from the end-user’s standpoint. One of the key advantages of this method is that testers do not require specific knowledge of programming languages or the implementation details of the system (16).

The black box testing conducted with 10 respondents yielded results as presented in Table 3. Out of 24 questions across 5 testing items, the outcomes showed 100% alignment with the predefined testing scenarios. This indicates that the user interface of the drug categorization feature performs in accordance with the design specifications developed by the researcher. Therefore, this feature is deemed suitable for broader user implementation. In this context, the intended users are pharmaceutical personnel working in healthcare and pharmacy settings.

Output Accuracy Testing: Application vs. Manual Calculation Using Microsoft Excel

The results demonstrate that the *Drug PC* application generates values and categorizations identical to those produced through manual calculation using Microsoft Excel. This indicates that the algorithm implemented in the application functions correctly and is appropriate for classifying drugs into ABC, VEN, and PUT categories, the latter representing the combined ABC-VEN classification. Accordingly, it can be concluded that the application is valid and reliable for use, as its output aligns with established manual methods.

ABC Classification

Based on the results presented above, the ABC drug classification for Sample 1 and Sample 2 yielded the following item distributions: Category A accounted for 9.82% and 19.71% of total drug items respectively; Category B for 21.17% and 36.76%; and Category C for 69.02% and 43.53%. In terms of investment value, Category A represented 65.87% and 74.99% (Rp 377,936,233 and Rp 989,983,638), Category B 3.87% and 19.96% (Rp 22,217,456 and Rp 263,538,427), and Category C 0.84% and 5.05% (Rp 4,817,471 and Rp 66,701,922). For Sample 1, the proportion of investment roughly followed the ideal 70:20:10 ratio, whereas Sample 2 deviated from this distribution. This deviation in Sample 2 might reflect

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differing procurement strategies. Hospital administrators at Sample 2 may have chosen to allocate more funds to a broader range of drugs (e.g., B or C categories), possibly to ensure wider availability, address local disease patterns, or reduce stock-outs. Category A drugs require strict monitoring of shelf life and stock levels, as unexpected shortages could result in costly emergency purchases. Enhancing inventory management for Category A drugs may lead to substantial savings in the hospital's drug budget. Procurement managers should focus on negotiating lower prices for Category A items by exploring more affordable dosage forms or alternative suppliers (12). The ABC analysis allows these high-priority drugs to be identified and subsequently evaluated. Such evaluations may determine whether high usage is justified or if more cost-effective alternatives are available (17).

VEN Classification

The VEN classification method categorizes drugs into Vital, Essential, and Non-Essential groups. In this study, Sample 1 and Sample 2 showed the following distributions based on the percentage of drug items: Vital (V) – 16.87% and 6.37%; Essential (E) – 73.31% and 72.69%; and Non-Essential (N) – 9.82% and 20.94%. In terms of investment value, the Vital group accounted for 9.74% and 2.89% (Rp 55,882,336 and Rp 38,202,974); the Essential group 85.42% and 86.49% (Rp 490,124,477 and Rp 1,141,874,658); and the Non-Essential group 4.84% and 10.62% (Rp 27,768,211 and Rp 140,146,355). The low percentage of drugs in the Non-Essential (N) category reflects their lower importance and criticality compared to the other groups. These items generally require shorter lead times for procurement (18). It is important to note that VEN classifications may vary between hospitals, depending on the specific availability and usage patterns at each institution.

ABC-VEN Matrix

The ABC-VEN matrix results indicated that the CE category (Category C and Essential) had the largest number of drug items. CE drugs are essential medications that are used in large quantities but have low investment values. These typically include drugs used for treating common conditions and are often priced affordably. In Sample 1 and Sample 2, CE items accounted for 51.23% and 29.57% of total items, with corresponding investment values of 4.09% and 3.27% (Rp 23,487,846 and Rp 43,162,248). From a financial perspective, the AE (Category A and Essential) group represented the highest investment in both samples, with values of 65.87% and 68.14% (Rp 377,936,233 and Rp 899,604,806). This group includes essential drugs with significant financial impact and should be the focus of strategic inventory management.

PUT Group (Primary, Urgent, and Tertiary)

The PUT group, an acronym representing priority classification, serves as an alternative approach for procurement prioritization. Within this system, drugs in the 'P' (Priority) category should never be out of stock, as they are vital to healthcare delivery and directly impact patient safety. All ABC classifications involving vital drugs (AV, BV, and CV) fall under this group. In both hospital samples, these are considered high-priority drugs for procurement. In the two hospital samples, the P category consisted of 55 items (16.87%) and 31 items (6.37%), with investment values of 2.48% and 2.89% (Rp 14,206,330 and Rp 38,202,974), respectively.

Group I, II, and III

Based on classification into Groups I, II, and III: Group I includes vital drugs with high cost or investment value. In both samples, Group I drugs comprised 25.15% and 25.46% of items, requiring 78.74% (Rp 451,802,909) and 76.70% (Rp 1,012,610,412) of the total drug budget. Conversely, Group III, specifically CN (Category C and Non-Essential) drugs, includes items with the lowest investment value. In Sample 1, this group accounted for 7.06% (23 items) and required only 0.19% of the budget (Rp 1,114,120). In Sample 2, it represented 10.47% (51 items) with 1.34% of the budget (Rp 17,736,715). These CN drugs are prime candidates for reduction or elimination. If budget constraints persist, further reductions may be applied to BN (Category B and Non-Essential) and, if necessary, to AN (Category A and Non-Essential) drugs (Abdurrahman et al., 2023).

Interpretation of Key Findings

The development and implementation of the Drug PC application demonstrated strong validity and functional reliability in categorizing pharmaceutical items using ABC, VEN, and ABC-VEN combination

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methods. The system successfully produced categorization results with 100% accuracy when compared to manual calculations in Microsoft Excel, confirming the correct implementation of its underlying algorithms. In usability testing through black-box methods, pharmacy staff responded positively, indicating that the application was user-friendly, easy to navigate, and functionally consistent with standard inventory management practices. This suggests that the Drug PC system has the potential to support more efficient and rational decision-making in pharmaceutical procurement and stock control.

Comparison with Previous Studies

The findings of this study are consistent with earlier literature emphasizing the importance of computerized inventory systems in healthcare. For instance, Satibi (2015) and Agus et al. (2023) support the integration of ABC-VEN analysis for identifying essential drugs while optimizing cost and ensuring availability (19,20). Similarly, studies by Gizaw & Jemal (2021) have shown that combining financial (ABC) and clinical (VEN) dimensions in inventory classification significantly improves resource prioritization (21). Unlike prior studies that focused on manual or Excel-based systems, this study contributes to the field by offering a web-based automated solution that reduces human error, increases efficiency, and provides real-time access to categorization results. This innovation represents a step forward in digital transformation in pharmaceutical management at the institutional level.

Limitations and Cautions

While the Drug PC application showed promising results in terms of accuracy and usability, this study has several limitations that must be acknowledged. First, the research was conducted using data from only two hospitals located in Central Sulawesi, which may not fully represent the diversity of healthcare settings in other regions. As such, the generalizability of the findings is limited. Second, the sample size for user testing was relatively small and restricted to a specific group of pharmacy personnel, which may not capture broader perspectives on user experience and operational challenges. Third, the study was cross-sectional in nature and did not include a longitudinal assessment to observe the application's performance or impact over time, such as its effectiveness in reducing drug stockouts, managing procurement cycles, or optimizing inventory levels. Lastly, external factors such as variations in internet connectivity and limitations in digital infrastructure in some healthcare facilities may hinder the application's consistent use, especially in remote or under-resourced areas.

Recommendations for Future Research

Future studies should aim to address these limitations by expanding the research scope to include a more diverse range of healthcare facilities across different geographic and institutional settings. This would provide a broader evaluation of the application's functionality and adaptability. It is also recommended that longitudinal studies be conducted to measure the long-term outcomes of using the Drug PC application, including improvements in inventory turnover, budget efficiency, and drug availability. Furthermore, future research could explore the development and integration of advanced features such as stock forecasting, expiry date monitoring, and automated restocking alerts to enhance the system's utility. Integrating the application with existing hospital information systems (HIS) or regional health information platforms could also improve data interoperability and streamline pharmaceutical logistics. Lastly, economic evaluations such as cost-benefit or cost-effectiveness analyses should be considered to determine the value and sustainability of implementing Drug PC in various healthcare environments.

CONCLUSION

In conclusion, this study successfully designed and implemented a drug categorization feature based on the ABC, VEN, and combined ABC-VEN methods within a user-friendly, web-based application. The feature demonstrated its potential to assist healthcare personnel in making informed decisions about drug procurement and inventory management. By automating complex categorization processes, the tool enhances efficiency, supports prioritization of essential and high-cost medications, and promotes more strategic resource allocation. Its practical utility in real hospital settings highlights its value as a supportive solution for improving pharmaceutical supply chain management.

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CONFLICTS OF INTEREST

The authors Muhamad Rinaldhi Tandah, Nurul Ambianti, Yenita Kartika Putri, and Khusnul Diana declare that there are no conflicts of interest regarding the publication of this research entitled "Development of Drug PC App Using ABC, VEN, and Combined Methods for Inventory Control."

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