



Araştırma

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DETERMINATION AND APPLICATION OF FORECASTING METHOD FOR MEDICINE CONSUMPTION IN HEALTHCARE ORGANIZATION  
SAĞLIK İŞLETMELERİNDE İLAÇ TÜKETİMİ İÇİN UYGUN TAHMİN YÖNTEMİNİN BELİRLENMESİ VE UYGULANMASI

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**ABSTRACT**

The aim of this research is to estimate the consumption of a selected medicine in a public hospital for the next 1-year period by choosing the most appropriate forecasting method. Kaptopril 5-mg tablets from January 2018 to December 2022 were examined. In this research, time series methods were applied to the existing data using the Minitab 18 program. Moving average, exponentials smoothing, and Holt-Winters forecasting methods were used in this study. Error measures such as mean absolute error, mean absolute percent error, and mean squared error were used to compare the methods. For Kaptopril 5 mg, the most appropriated and forecasting method according to error measures is the Multiplicative Holt-Winters Method. According to this method, the mean absolute percent error is 37.23. According to the multiplicative Holt-Winters model, the total medicine consumption in 2023 was found to be 145 tablets. This research shows that time series forecasting methods can be applied to help reliable decision making in stock management of medicines by making a sample application on a selected medicine in a public hospital.

**Keywords:** material management, pharmaceutical products, time series.

**ÖZ**

Bu araştırmanın amacı, bir devlet hastanesinde seçilen bir ilacın tüketiminin en uygun tahmin yöntemi seçilerek gelecek 1 yıllık dönem için tahmin edilmesidir. Araştırmada, 2018 yılı Ocak ayından, 2022 yılı Aralık ayına uzanan süreçteki 60 aylık Kaptopril 5 mg tablet için ilaç tüketim verileri incelenmiştir. Araştırmada Minitab18 programı kullanılarak mevcut verilere zaman serisi yöntemleri uygulanmıştır. Araştırmada talep tahmin yöntemlerinden hareketli ortalama, üstel düzeltme, Holt-Winters yöntemleri kullanılmıştır. Yöntemlerin karşılaştırılmasında ortalama mutlak hata, ortalama mutlak hata yüzdesi ve hata karelerinin ortalaması gibi hata ölçütleri kullanılmıştır. Kaptopril 5 mg için hata ölçütlerine göre en uygun talep tahmini yöntemi Çarpımsal Holt-Winters yöntemidir. Bu yöntemle göre ortalama mutlak yüzde hata değeri 37.23'dür. Çarpımsal Holt-Winters modeline göre 2023 yılında toplam ilaç tüketiminin 145 olacağı bulunmuştur. Bu araştırma, bir devlet hastanesinde, seçilen bir ilaç üzerinde örnek uygulama yapılarak, ilaçların stok yönetiminde güvenilir olarak karar vermeye yardımcı olacak zaman serisi tahmin yöntemlerinin uygulanabileceğini göstermektedir.

**Anahtar kelimeler:** malzeme yönetimi, eczacılıkla ilgili ürünler, zaman serisi.

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## INTRODUCTION

In health institutions, it is possible to ensure that the service delivery is not interrupted, and when the need for material arises, it can be provided in the desired amount, at the desired time, in quality, and economically thanks to the correct material management.<sup>1</sup> Most of the goods required to be kept in health institutions are quite expensive and can deteriorate in a short time. There is a risk of obsolescence of these products. Keeping excessive stocks brings burdens such as storage and personnel costs and prevents the efficient use of resources.<sup>2</sup>

Health institutions must use their resources effectively and efficiently to provide uninterrupted service. Medical supplies constitute the item with the highest weight after personnel expenses in health institutions.<sup>3</sup> Material planning using demand forecasting methods provides cost savings.<sup>4</sup> It is thought that health managers have an important role in this regard. Health managers should be able to use, analyze, and infer data. They should be able to use the data they have obtained to make predictions for the future.<sup>5</sup>

In the studies where forecasting methods are applied in health institutions, demand forecasting studies are conducted in which the number of patients, such as out-patient forecasting, the number of surgeries, and the number of in-patients, is estimated using the Holt method, trend analysis, moving average, Random Forest Regression method, Box-Jenkins method.<sup>6-9</sup> In addition, studies using Holt-Winters, regression, moving average and exponential smoothing and regression analysis on materials management, such as drugs, surgical gauze used in intensive care, injectors, and medical supplies such as medicines.<sup>3,4,10,11</sup>

Forecasting methods can be used to avoid unnecessary or missing stocks in health institutions. This research aims to analyze the consumption of a selected drug in a public hospital using forecasting methods, to select the most appropriate forecasting method according to the error criteria, and to predict drug consumption in the next 1-year period. This research will guide the selection of methods to be used in material planning in health institutions and more specifically in the selection of methods that can be used in the hospital pharmacy.

## MATERIALS AND METHODS

The study was planned as a descriptive, single-center study. In this study, the most appropriate estimation method was selected for the consumption of a selected drug in a public hospital, and drug consumption was estimated for the next 1-year period. The hospital is an All-group public hospital with 450 patient beds. In this study, moving average, exponential smoothing, and Holt-Winters forecasting methods were used. In this context, it is aimed to determine the most appropriate forecasting method. The values of error criteria such as Mean Absolute Error (MAE), Mean Absolute Error Percentage (MAEP), and Mean Square Error (MSE) were determined in measuring the accuracy of the forecasting results and comparing the methods to decide on the most appropriate method.<sup>12</sup>

In this study, 60-month Captopril 5 mg tablet drug consumption data for the period from January 2018 to December 2022 were analyzed. This drug was selected

because it is included in the WHO essential drug list and is used in the treatment of cardiovascular diseases. Captopril 5 mg is a drug that helps lower blood pressure and is used for treating high blood pressure (hypertension), heart failure, and heart attack (myocardial infarction).<sup>13</sup>

In the research, time series methods were applied to the available data using the Minitab 18 program. The time series method is the results observed in periods such as daily, weekly, or monthly. The time series method aims to determine the expected behavior in the future by explaining the trend of the variable in the past years. Using the past values of the observations in the series, future values can be estimated.<sup>5</sup>

As the data included a ready dataset and secondary data, this study did not require approval from an ethics committee or informed consent. Institutional permission was obtained from the hospital management for the implementation of the study (13.06.2023/217776859).

### Examination of the Assumptions

Using the 3 and 5-month moving average method, if there are obvious trends or seasonality in the time series data, the simple moving average may not capture these patterns. This assumption was tested by trend analysis. In the single exponential smoothing method, appropriate selection of the weight parameter is important. This selection was made by trial and error. For the Holt-Winters method, the data set must be stationary. This assumption was examined using the Augmented Dickey-Fuller Test. In addition, normality was determined by the Jarque-Bera test; the autocorrelation assumption was tested graphically.

## RESULTS

To determine which forecasting methods can be successful in the research, trend analysis was performed using the Minitab 18 program. In the trend analysis graph in Figure 1, the x-axis represents months and the y-axis represents drug consumption. According to the trend analysis, it was determined that drug consumption was not constant but decreased in certain months and increased in certain months. Based on the years, it was determined that consumption showed a decreasing trend in the summer and an increasing trend in the winter.

In the analysis performed according to the 3-month moving average method to determine the drug requirement, the MAPE value was 39.3 and the MAD

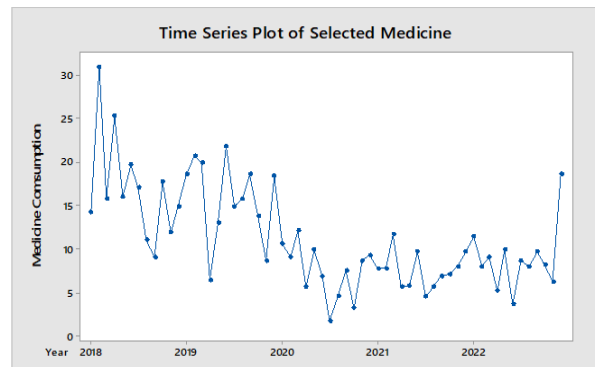


Figure 1: Trend Analysis

value was 3.22. In the analysis performed according to the 5-month moving average method to predict future drug consumption, the MAPE value was 43.8 and the MAD value was 3.3 (Figure2). The error rate increased as the number of months included in the moving average increased.

In the simple exponentials moothing method, the drug consumption estimation with correction coefficient  $\alpha=0.8$  has shown in Figure 3. When the correction coefficient is  $\alpha=0.8$ , the MAPE value is 45 with a MAD value of 4.

As a result of the analysis, MAPE in the additive Holt-

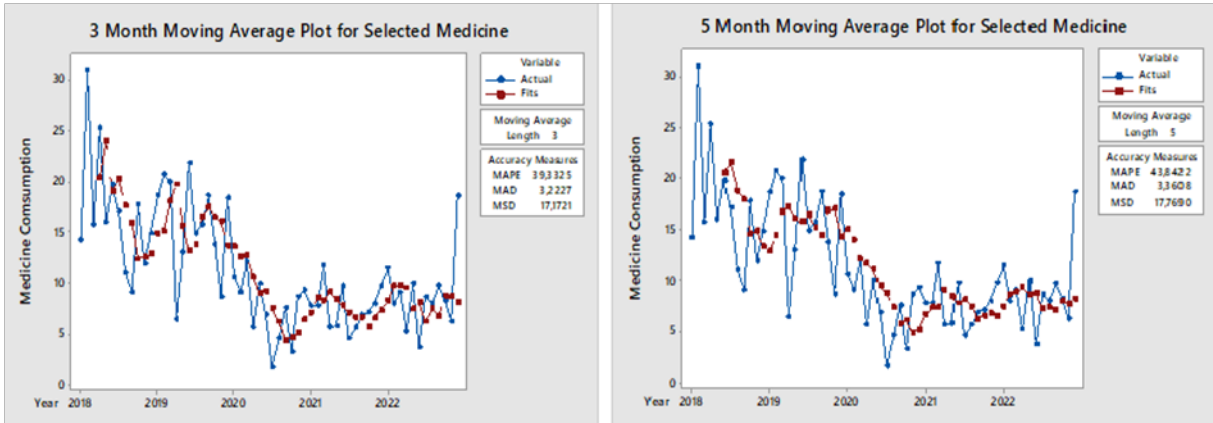


Figure 2: 3 and 5 Month Moving Average Graphs

In the simple exponential correction method, drug consumption was estimated with correction coefficients  $\alpha=0.2$ ,  $\alpha=0.5$ , and  $\alpha=0.8$ . When the correction coefficient was  $\alpha=0.2$ , the MAPE value was 41.2 and the MAD value was 3.6 (Figure 3). In the simple exponentials moothing method, the drug consumption estimation with correction coefficient  $\alpha=0.5$  has shown in Figure 3. When the correction coefficient  $\alpha=0.5$ , the MAPE value is 41.2 and the MAD value is 3.6.

Winters model was 37.25 and MAD was 3.51, where as MAPE in the multiplicative model was 37.23 and MAD was 3.5. The model with the lowest error rate was found to be the additive Holt-Winters model (Figure 4).

Table 1 shows the mean absolute percent age error (MAPE), mean absolute error (MAE), and means quare error (MSE) values, i.e., error measures, obtained at the end of the demand forecasting methods applied for pharmaceutical consumption.

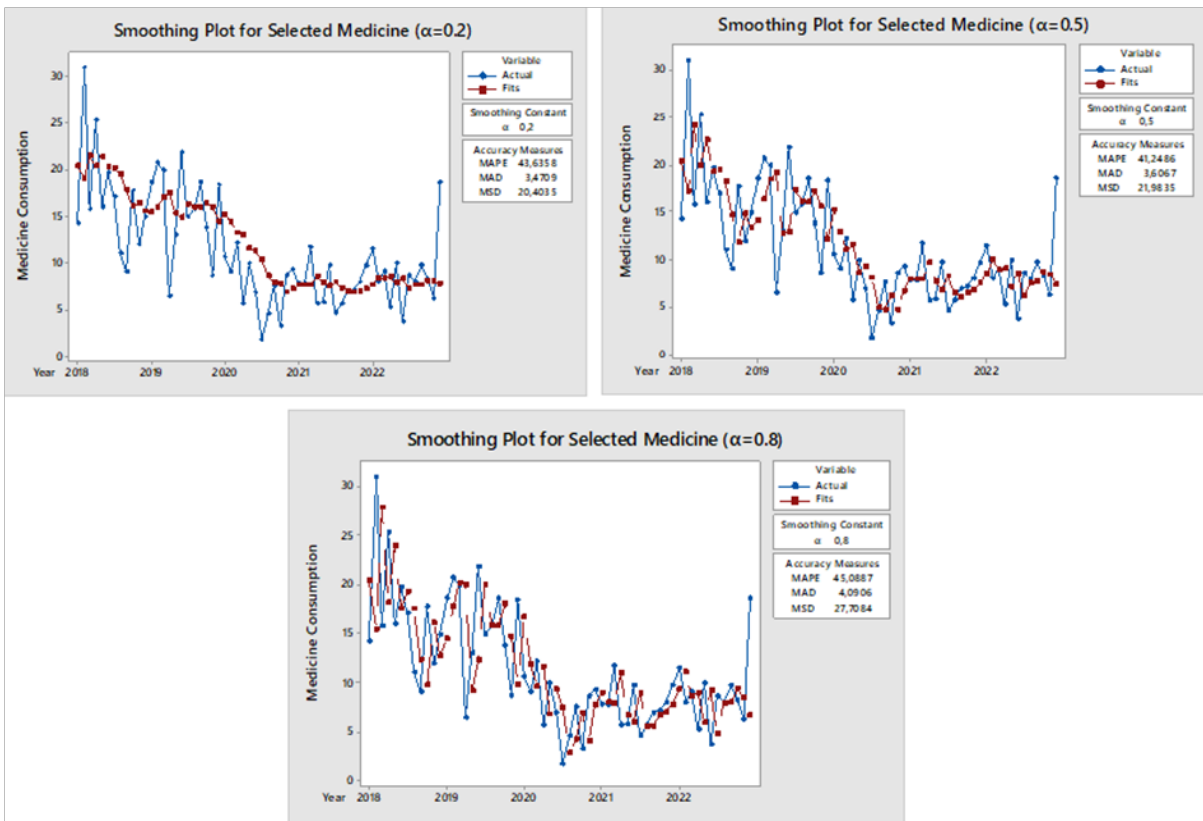


Figure 3: Simple Exponential Smoothing Method Graphs ( $\alpha=0.2$ ;  $\alpha=0.5$ ;  $\alpha=0.8$ )

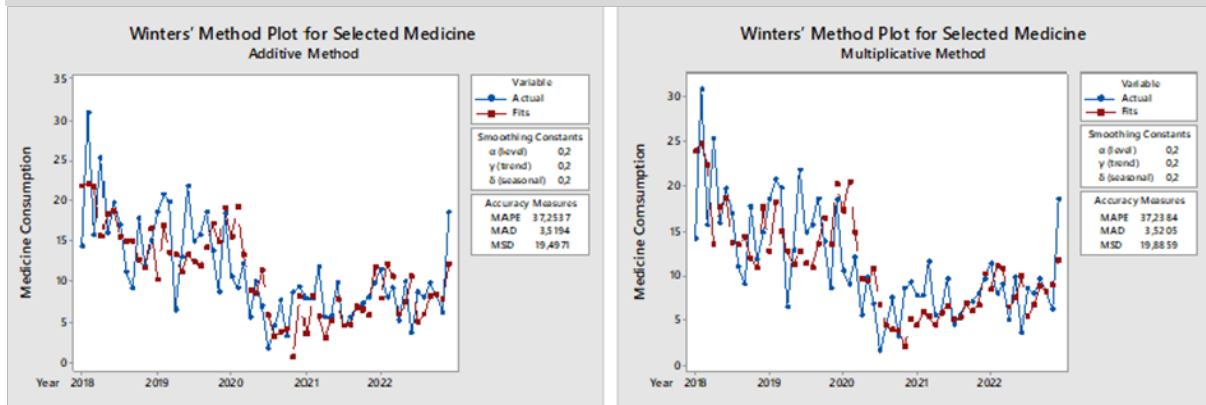


Figure 4: Additive and Multiplicative Holt-Winters Method Graphs

The most appropriate demand estimation method for captopril 5 mg according to the error criteria is the Multiplicative Holt-Winters Method. According to this method, the MAPE value is 37.23 (Table 1). MAPE allows the comparison of results obtained from different models applied to different time series. This statistic represents the average of the absolute differences between the predicted and observed values as a percentage. A small MAPE value indicates a model that fits the data well.<sup>14</sup> If the MAPE value is less than 10%, the prediction is considered to be highly accurate, whereas if the value is more than 10% and less than 20%, it is considered to be a good prediction. If it is greater than 20% and less than 50%, the prediction is

acceptable, and when the MAPE is greater than 50%, the prediction is considered incorrect.<sup>15</sup> As a result of the comparison, future 12-month drug consumption was estimated (Table 2). According to the multiplicative Holt-Winters model, the total drug consumption in 2023 was found to be 145 tablets.

**DISCUSSION**

The health sector is a sector that deals with human life, it also stands out in the service sector. Managers have a great responsibility to ensure effective material management in hospitals. Uninterrupted and effective provision of health services is also an indicator of development levels.<sup>16</sup> Materials management in health

Table 1. Error Criteria According to Methods

Methods	OMHY (MAPE)	OMH (MAE)	HKO (MSE)
3 Month Moving Average	39.33	3.22	17.17
5 Month Moving Average	43.84	3.36	17.17
Single Exponential Correction (0,2)	43.63	3.47	20.40
Single Exponential Correction (0,5)	41.24	3.60	21.98
Single Exponential Correction (0,8)	45.08	4.09	27.70
Summative Holt-Winters Method	37.25	3.51	19.49
Multiplicative Holt-Winters Method	37.23	3.52	19.88

Table 2. 1-Year Drug Consumption Fore cast for the Future

Term	3 Month Moving Average	5 Month Moving Average	Single Exponential Smoothing (0,2)	Single Exponential Smoothing (0,5)	Single Exponential Smoothing (0,8)	Summative Holt-Winters Method	Multiplicative Holt-Winters Method <sup>a</sup>
Jan.2023	11.01	10.15	9.90	12.96	16.20	10.96	11.74
Feb.2023	11.01	10.15	9.90	12.96	16.20	13.37	12.92
Mar.2023	11.01	10.15	9.90	12.96	16.20	13.25	13.67
Apr.2023	11.01	10.15	9.90	12.96	16.20	9.38	8.56
May.2023	11.01	10.15	9.90	12.96	16.20	11.71	11.40
June.2023	11.01	10.15	9.90	12.96	16.20	13.08	12.06
Jul.2023	11.01	10.15	9.90	12.96	16.20	11.18	9.58
Aug.2023	11.01	10.15	9.90	12.96	16.20	11.48	10.24
Sep.2023	11.01	10.15	9.90	12.96	16.20	13.39	12.82
Oct.2023	11.01	10.15	9.90	12.96	16.20	13.20	11.59
Nov.2023	11.01	10.15	9.90	12.96	16.20	12.63	11.90
Dec.2023	11.01	10.15	9.90	12.96	16.20	18.81	19.24
Total	132.20	121.82	118.88	155.62	194.43	152.49	145.78

<sup>a</sup>: The most appropriated demand forecasting method. The unit of medicine is a tablet.

services consists of the selection, procurement, distribution, and use of these sources required to provide health services, such as medicines and equipment. Materials management ensures that the limited resources in health institutions are used most appropriately and that the negative consequences of the deficiency are minimized. If material management is not done correctly, there is over or under-stocking.<sup>17</sup>

In this study, 5-year consumption data of Captopril 5 mg, which is used for treating cardiovascular diseases and included in the WHO essential drugs list, were analyzed and 12-month consumption for the future was estimated. According to the trend analysis, it was determined that drug consumption is not constant, it shows a decreasing trend in summer months and an increasing trend in winter months. It is thought that the decreasing drug consumption trend in the summer months is generally because fewer patients apply to hospitals for treatment in the summer months.

In this study, to determine the most appropriate forecasting method among the moving average, exponentials smoothing, and Holt-Winters forecasting methods, the most appropriate method was found to be the Multiplicative Holt-Winters Method when the values of error criteria such as Mean Absolute Error (MAE), Mean Absolute Error Percentage (MAEP), and Mean Square Error (MSE) were analyzed. According to the multiplicative Holt-Winters model, total drug consumption in 2023 was found to be 145 tablets. Sarı and Gül applied time series methods to 36-month sales data of a domestic drug. In their research, they used ARIMA, exponentials smoothing, artificial neural networks, and the Holt-Winters method. They found that the method that gives the best forecasting result is the integrated ANN model.<sup>18</sup> Uçakkuş and Koçyiğit used moving average, Holt-Winters method, and exponentials smoothing methods in their research, in which they estimated surgical gauze consumption in intensive care and found that the method with the least error rate was the moving average method.<sup>4</sup> Özüdoğru and Görener applied moving average, exponentials smoothing, Holt-Winters method, and regression analysis to predict syringe consumption from medical supplies in a hospital in Istanbul. They found that the most appropriate method is the 5-month moving average method.<sup>12</sup>

Bon and Ng analyzed the consumption of Panadol 650 mg for 68 months using different methods such as moving average, single exponentials smoothing, double exponentials smoothing, regression, additive Holt-Winters, multiplicative Holt-Winters, and ARIMA and found that regression analysis was the best prediction method.<sup>19</sup> Mbonyinshut et al. analyzed the top ten most used essential medicines; cotrimoxazole 480 mg, amoxicillin 250 mg, paracetamol 500 mg, oral rehydrationsalts 20.5 g, chlorpheniramine 4 mg, nevirapine 200 mg, aminophylline 100 mg, artemether 20 mg+lumefantrine (AL) 120 mg, and cromoglycateophthalmic based on consumption data between 2015-2019. Linear regression, artificial neural network, and random forest from machine learning applications were used to predict future trends in the demand for essential medicines in Rwanda. Random forest could predict with 88 percent accuracy. The

Random Forest model performed well as a forecasting model for the demand for essential medicines.<sup>20</sup>

The data of this research covers the period from January 2018 to December 2022. These dates coincide with the COVID-19 outbreak. The impact of the COVID-19 on medicine consumption has been examined by researchers. Gimbach et al. examined the impact of the COVID-19 pandemic on attention deficit hyperactivity disorder (ADHD) medication consumption. They found that ADHD medication consumption decreased in 2020 but increased as of 2021.<sup>21</sup> Vukićević et al. found that the COVID-19 pandemic in Croatia used an increase in the consumption of antipsychotics, anxiolytics, hypnotics and tranquilizers, and anti-depressants.<sup>22</sup> Barrett et al. found reductions in the prescribing of ACE inhibitors, beta-blockers, calcium channel blockers, statins, antiplatelet, antithrombotics, ARBs, loop diuretics, doxazosin, bendroflumethiazide, nitrates, and indapamide after the pandemic began (March-October 2020).<sup>23</sup> It is also useful to consider that the medicine examined in this research is used for treating high blood pressure (hypertension), heart failure, and heart attack (myocardial infarction). Mathieu et al. stated that the pandemic and related measures had a significant impact on the decrease in the use of cardiovascular and antidiabetic medicines in France, and that this was due to the decrease in treatments during the quarantine.<sup>24</sup> The medicine consumption examined in this research also tended to decrease in the following years compared to 2018 and 2019. The COVID-19 may have had an impact on this decrease.

Accuracy is an element that contributes to planning. Analyzing periodic consumption data to estimate the demand for pharmaceuticals is important for making predictive decisions for the future. As a result, cost savings will be achieved in pharmaceutical supply and storage activities. To make strategic decisions in the pharmaceutical sector, past period data can be analyzed and forecasts for future consumption can be used. Thus, the risk of being affected by fluctuations in drug prices and the difficulties encountered in drug storage in health institutions can be reduced and productivity can be increased.<sup>18</sup> Keeping the right amount of stock in health institutions means not incurring inventory holding costs and being able to respond to health demand.

## CONCLUSION

Health institutions have different categories of products, such as medicines, medical consumables, cleaning products, and stationery materials. Because medicines are products that are vital to be supplied as soon as they are needed, need to be stored in appropriate conditions, and have expiry dates, it is important to determine the consumption of medicines for the future. In the study, the most appropriate method was found to be the Multiplicative Holt-Winters Method. According to the method, the total medicine consumption in 2023 was found to be 145 tablets.

As a result of this research, by making a sample application on a selected medicine in a state hospital, time series forecasting methods can be applied to help reliable decision-making in the inventory management of medicines. It is recommended that these methods



should be used in the hospital pharmacies as decision support systems to help the mavidover stock or under stock problems and improve inventory management.

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