

Implementation of Forecasting with the Monte Carlo Simulation Method to Predict Supply and Demand for Psychotropic Drug Products

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ABSTRACT

The availability of drugs is one of the needs that supports the presence of health in the community. Patient certainty regarding the availability of drugs becomes increasingly important for patients who use psychotropic drugs. This type is a dangerous drug and needs to be controlled. Control is carried out to avoid drug abuse outside of medical purposes. Two conflicting sides between the importance of ensuring the availability and controlling their use can be resolved, one of which is by measuring supply and demand. The availability of psychotropic drugs should be adjusted to demand. The problem is that we cannot know demand that has not yet occurred, drugs have an expiration date, and procuring drugs takes time. One way is to predict the demand when supplying drugs so that the order quantity is appropriate. The prediction method used is the Monte Carlo Simulation Method. One example of implementation is the Economic Order Quantity (EOQ) Method. As a result, the Monte Carlo method successfully made predictions based on existing data. In addition, it was found that the Monte Carlo Method tended to the distribution of the data used. The closer the distance between the data, the higher the prediction accuracy obtained. Uncertainty in actual demand is also a big challenge for producing accurate predictions based on patterns. Prediction results will be more accurate with more data patterns and variations. Implementation of prediction results with EOQ makes the number of drugs that should be ordered based on demand that is likely to occur.

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INTRODUCTION

The supply of pharmaceutical raw materials is usually regulated by pharmaceutical manufacturing regulations, which refer to available raw materials. One of the problems that often occurs in the pharmaceutical industry is that the industry does not prepare the right supply of raw materials to meet market demand. (Eunice et al., 2018). Currently, the need for drugs is very high. It often happens in the drug manufacturing industry that the number of drugs produced is more than consumed by the public, but the amount of drugs produced is less than consumed, which results in a buildup of drugs that are not used until they expire.

For this reason, it is important to create a simulation design that can be used to predict the supply of medicinal products, especially psychotropic drugs, based on consumer demand in society. This initiation is carried out so that predictions of drug demand do not result in shortages or excesses of drug products.

Monte Carlo simulation is a probabilistic simulation in which a randomization process solves the problem. This random process involves probability distributions of data variables collected from previous data and theoretical probability distributions. Monte Carlo simulation is used to model and analyze systems that contain risk and uncertainty. That is a probabilistic simulation with a randomization process to solve a problem. The Monte Carlo method uses random values for each variable based on its probability distribution to simulate the system repeatedly, perhaps hundreds or thousands of times, depending on the system under consideration.

To provide an overview and consideration of inventory management, the Monte Carlo method is usually used to predict the amount of demand for medicines and make stock estimates to guard against excess or shortage of inventory that cannot be predicted with certainty. All this is done so that drug demand can be managed well. Because the Monte Carlo method requires a lot of random numbers, better random number generators have emerged for the random number tables that were previously often used for statistical sampling.

This research will likely solve the problem of drug supplies in pharmacy X by producing balance in the procurement of drug supplies. This research aims to minimize costs associated with drug supplies and predict the number of future requests to avoid shortages in fulfilling demand. Previous research was conducted by (Ilmi et al., 2021) aims to estimate the rate of return on mutual fund investments (MFI) with the assistance of the Monte Carlo Simulation (MCS), giving investors a choice of the average demand for return on mutual funds (MFR) that they require. Based on a 48-time trial frequency and analysis of the rate of return on MFI and the forecast of NAV movements in 55 MFP, we can estimate the average demand for MFR of 37 out of 100 cumulative numbers of probability distributions. Research on



stock inventory prediction has been conducted previously by (Rani Purbaningtyas, 2023) used the Monte Carlo technique is used as the approach to forecast sales statistics for Narendra's cookies. The same research on stock inventory prediction has been carried out by (Caesarramzy et al., 2018) to execute forecasts in order to do computations utilising the Periodic Review technique, the request makes use of a Monte Carlo simulation, the results of which will be entered to carry out calculations using the Periodic Review method. In research (Mulia & Nurcahyo, 2022), Monte Carlo simulations are used to predict chronic drug use. So that health workers can make decisions about which drugs should be prescribed to patients.

LITERATURE REVIEW

A literature review is a critical, analytical summary and synthesis of the current knowledge of a topic. It should compare and relate different theories/research, findings, and so on, rather than just summarize them individually. It should also have a particular focus or theme to organize the review. In this section, the researcher can describe some of the related previous studies. Researchers can review the gaps in the research, then it can be used as a basis for research to be carried out.

According to Health Law No. 36 of 2009, drugs are substances or combinations of substances, including biological products, which influence biological systems or pathological conditions in reducing pain and treating or preventing human disease (Indonesian Department of Health, 2009). health sector, which is important in improving the level of public health. According to Minister of Health Regulation 87 of 2013, drugs are substances or combinations of substances used to influence or investigate physiological systems or pathological conditions to determine diagnosis, prevention, healing, recovery, improving health and contraception, including biological products. Therefore, the drug is an important component that health services cannot replace.

A class of drugs can be part of Psychotropics. This group of substances are substances which, if they enter the body in excess, especially affect the function of the brain and nerves (central nervous system) to produce a calming effect. This drug often causes dependence because it works by increasing the effects of certain natural chemicals in the body, which will later cause changes in the user's awareness, thoughts, feelings and behaviour. Psychotropics, on the one hand, are drugs or substances that are useful in the field of medicine or health services and the development of science. On the other hand, they can cause dependence, which is very detrimental if used without strict and thorough control and supervision. The development of psychotropic abuse is increasing, prompting the Indonesian Government to issue the Law on Psychotropic Substances. According to the Republic of Indonesia Law no. 5 of 1997, Psychotropics are substances or drugs, both natural and synthetic, non-narcotic, which have psychoactive properties through selective influence on the central nervous system, which causes characteristic changes in mental activity and behaviour. Psychotropics consist of 4 groups.

- a. Group I: Psychotropics can only be used for scientific purposes, are not used in therapy, and have the potential to cause a dependency syndrome (for example, Ecstasy).
- b. Group II: Psychotropics that have medicinal properties and can be used in therapy and for scientific purposes and have the strong potential to cause dependency syndrome (example: Amphetamine).
- c. Group III: Psychotropics that have medicinal properties and are widely used in therapy or for scientific purposes and have moderate potential to cause dependency syndrome (example: Phenobarbital).
- d. Group IV: Psychotropics that have drug properties are widely used in therapy or for scientific purposes and have a mild potential to cause dependency syndrome (e.g. Diazepam, Nitrazepam (BK, DUM)). (2014)

Prediction is a process of systematically estimating something that is most likely to happen in the future based on the available past and present information so that the error (the difference between something that happens and the predicted result) can be minimized. Predictions do not have to provide definite answers to events but try to find answers as close as possible to what will happen. (Herdianto, 2013). The meaning of prediction is the same as prediction or estimation. According to the Big Indonesian Dictionary, prediction is the result of the activity of predicting, forecasting or estimating future values using past data. Predictions show what will happen in a particular situation and are input for the planning and decision-making. Predictions can be based on scientific methods or purely subjective. For example, weather predictions are always based on the latest data and information based on observations, including by satellites.

Predictions will be easier to digest with representation in the form of simulations. Simulation is a technique of imitating operations or processes that occur in a system with the help of computer devices and is based on certain assumptions so that the system can be studied scientifically (Law and Kelton, 1991). In simulation, a computer is used to study the system numerically, where data is collected to carry out statistical estimates to obtain the original characteristics of the system. Simulation is the right tool to use, especially if you must conduct experiments to find the best choice from system components. That way is because it is costly and takes a long time if the experiment is tried in real life. By carrying out a simulation study, the right decision can be made quickly and at a manageable cost because everything can be done using a computer. The simulation approach begins with building an accurate system model. The model must be able to show how the various components in the system interact with each other to describe the system's

behaviour honestly. After the model is created, it is transformed into a computer program to be simulated.

A popular simulation method is the Monte Carlo Method. Monte Carlo simulation is defined as all statistical sampling techniques used to estimate solutions to quantitative problems (Monte Carlo Method, 2008). In Monte Carlo simulation, a model is built based on the actual system. Each variable in the model has a value that has a different probability, which is shown by the probability distribution or what is usually called the probability distribution function (PDF) of each variable. The Monte Carlo method simulates the system repeatedly, hundreds or thousands of times, depending on the system being considered, by selecting a random value for each variable from its probability distribution. The results obtained from the simulation are a probability distribution of the values of a system as a whole. Monte Carlo simulation has been applied in various fields, including project management, transportation, computer design, finance, meteorology, biology and biochemistry (Kwak & Ingall, 2007).

METHOD

The variables used consist of dependent variables and independent variables. The independent variable is the variable that has an effect or influence, while the dependent variable is the response variable or variable that is influenced by the independent variable. The following variables used in this research include:

Dependent Variable

Optimal availability of drugs.

Independent Variable

Included in the independent variables in this research are:

- a. Drug Data (All kinds of medicines are available in pharmacies.)
- b. Drug Prices (The selling price for each type of medicine is determined by the pharmacy to be sold to buyers.)
- c. Drug Demand Data
 - 1) Monthly Drug Demand, Calculated from the total drug requests of buyers every month.
 - 2) Annual Drug Demand, This data is collected from buyers' total drug requests each year.
- d. Order Fees (This data describes the total price of each drug order made to reorder the drug from the supplier.)
- e. Storage Fees (These data describe the costs associated with stored medications.)
- f. Lead Time (The time needed to wait for the raw materials ordered by the customer to arrive in the hands of the brand.)

$$Error = \frac{Difference}{Actual} \quad (1)$$

One way to measure the accuracy of forecasting is by percentage error. The difference between the actual and predicted values is compared to the actual value (1). This method produces how significant the prediction results are from the reality that occurs with mean average percentage error (Cruz-Nájera et al, 2022).

$$EOQ = \sqrt{\frac{2SD}{H}} \quad (2)$$

An example of implementing forecasting in this research is Economic Order Quantity (EOQ). An approach to measuring the optimal quantity in ordering goods, in this case, is ordering drugs. The results of the predicted demand (D) and the ordering costs (S) must be adjusted to the storage costs (H) shown in formula (2).

RESULT

This simulation determines inventory forecasting for January 2024 to December 2024 using this method by simply generating random numbers, such as supplies of Phenobarbital and Sedatin. There are the following steps for Monte Carlo simulation:

- a. Find the probability distribution of the number of requests.
- b. Calculates the cumulative distribution.
- c. The first cumulative probability is the possibility of the first data appearing, the second cumulative potential is the possibility of the first cumulative appearing added to the second cumulative potential.
- d. Find random number intervals in the demand section for each month. After that, a random number will be obtained. Random numbers are matched to random number intervals
- e. Next, to find out the results of the drug demand simulation, the demand data is compared with real data after the random number interval is known.

Table 1. Phenobarbital Drug Supplies

Month	Phenobarbital	Probability	Commulative Probability	Intervals	Random Number	Simulation
January	825	0.087845	0.087845	0 - 0.087845	0.346834	785
February	782	0.095596	0.183442	0.087846 - 0.183442	0.765054	961
March	851	0.088182	0.271624	0.183443 - 0.271624	0.406731	944
April	785	0.106044	0.377668	0.271625 - 0.377668	0.583657	357
May	944	0.087059	0.464727	0.377669 - 0.464727	0.350788	785
June	775	0.040103	0.50483	0.464728 - 0.50483	0.769849	961
July	357	0.10492	0.609751	0.50484 - 0.609751	0.216056	851
August	934	0.107953	0.717704	0.609752 - 0.717704	0.664995	934
September	961	0.053134	0.770838	0.717705 - 0.770838	0.9255	777
October	473	0.054594	0.825432	0.770839 - 0.825432	0.262498	851
November	486	0.087284	0.912716	0.825433 - 0.912716	0.980891	777
December	486	0.087284	1	0.912716 - 1	0.989179	777
Total	8950					9760

Table 2. Phenobarbital Drug Demands

Month	Phenobarbital	Probability	Commulative Probability	Intervals	Random Number	Simulation
January	41	0.066667	0.066667	0 - 0.066667	0.767644	70
February	95	0.154472	0.221138	0.066668 - 0.221138	0.907934	13
March	56	0.091057	0.312195	0.221139 - 0.312195	0.141652	95
April	63	0.102439	0.414634	0.312196 - 0.414634	0.421456	33
May	33	0.053659	0.468293	0.414635 - 0.468293	0.725584	70
June	80	0.130081	0.598374	0.468294 - 0.598374	0.910657	13
July	47	0.076423	0.674797	0.598375 - 0.674797	0.235687	56
August	70	0.113821	0.788618	0.674798 - 0.788618	0.909726	13
September	18	0.029268	0.817886	0.788619 - 0.817886	0.187088	95
October	45	0.073171	0.891057	0.817887 - 0.891057	0.814345	18
November	13	0.021138	0.912195	0.891058 - 0.912195	0.941141	54
December	54	0.087805	1	0.912195 - 1	0.051404	41
Total	615					460

Table 1 is a random number result for the supply of phenobarbital drugs, while Table 2 is a random number result for the demand for phenobarbital drugs. The use of random numbers is only found in the sixth column. This step is useful for providing simulations of unpredictable supply or demand values. The same method is also used for the Sedatin in Table 3 and Table 4.

Table 3. Sedatin Drug Supplies

Month	Sedatin	Probability	Commulative Probability	Intervals	Random Number	Simulation
January	932	0.122664	0.122664	0 - 0.122664	0.525676	120
February	994	0.130824	0.253488	0.122665 - 0.253488	0.58004	203
March	294	0.038694	0.292182	0.253489 - 0.292182	0.659278	765
April	764	0.100553	0.392735	0.292183 - 0.392735	0.309411	764
May	979	0.12885	0.521585	0.392736 - 0.521585	0.769438	625
June	120	0.015794	0.537378	0.521586 - 0.537378	0.851603	663
July	273	0.035931	0.573309	0.537379 - 0.573309	0.189777	994
August	203	0.026718	0.600026	0.573310 - 0.600026	0.705849	625
September	765	0.100684	0.700711	0.600027 - 0.700711	0.290198	294
October	625	0.082258	0.782969	0.700712 - 0.782969	0.804257	663
November	663	0.08726	0.870229	0.782970 - 0.870229	0.502366	979
December	986	0.129771	1	0.870230 - 1	0.443184	979
Total	7598					7674

Table 4. Sedatin Drug Demands

Month	Sedatin	Probability	Commulative Probability	Intervals	Random Number	Simulation
January	91	0.143533	0.143533	0-0.143533	0.800724	84
February	14	0.022082	0.165615	0.143534-0.165615	0.30571	96
March	96	0.15142	0.317035	0.165616-0.317035	0.027831	91
April	22	0.0347	0.351735	0.317036-0.351735	0.558004	49
May	46	0.072555	0.42429	0.351736-0.42429	0.745074	84
June	59	0.09306	0.51735	0.42430-0.51735	0.81643	84
July	49	0.077287	0.594637	0.51736-0.594637	0.793301	84
August	88	0.138801	0.733438	0.594638-0.733438	0.910405	40
September	84	0.132492	0.865931	0.733439-0.865931	0.811686	84
October	40	0.063091	0.929022	0.865932-0.929022	0.760214	84
November	16	0.025237	0.954259	0.929023-0.954259	0.771174	84
December	29	0.045741	1	0.954260-1	0.039968	91
Total	634					955

Tables 1 to Table 4 consist of the actual values of drug supply and demand, the probability that it will happen again based on the total in a year, the cumulative probability of differentiating each month, the interval between the cumulative possibilities, the random value, and the results of the simulation of repeating the true value according to the month. The same steps as Table 3 and Table 4 are carried out for other drugs in Table 5. Some other drugs tested in the same ways are Lexotam, Valium, and Rohypnol.

Table 5. Drug Supply and Demand

No	Drug Name	Supply	Supply Prediction	Demand	Demand Prediction
1	Phenobarbital	8950	9760	615	460
2	Sedatin	7598	7674	634	955
3	Lexotam	4430	4654	412	356
4	Valium	6520	6456	327	246
5	Rohypnol	1530	1460	148	100

After obtaining a lot of demand in the next period, we can look for the Economic Order Quantity (EOQ) values. EOQ are one approach to determining the most economical order quantity. The EOQ calculation for the drug phenobarbital simulation can be shown in formula (1).

$$EOQ_{Phenobarbital} = \sqrt{\frac{2SD}{H}} = \sqrt{\frac{2(8000)(460)}{2000}} = 658.53 \quad (3)$$

In formula (3), it is assumed that the Supplier is willing to fulfill orders with an annual demand for Phenobarbital (D) 460 drugs. The ordering fee (S) is 8000 Rupiah, and the storage fee (H) is 2000 Rupiah. The EOQ value obtained was 658.53, meaning that the efficient number of drugs to order was 659 Phenobarbital drugs. One box of Phenobarbital consists of 30 strips, so the ideal number to order is 22 boxes.

$$EOQ_{Sedatin} = \sqrt{\frac{2SD}{H}} = \sqrt{\frac{2(8000)(955)}{2000}} = 1358.57 \quad (4)$$

The same method is used for the drug Sedatin (4). The result is that the EOQ value as a value that shows the optimal number of orders is 1359 drugs. One box of Sedatin consists of 30 strips, so the ideal number to order is 45 boxes.

Table 6. Economic Order Quantity (EOQ)

No	Drug Name	Demand Prediction	EOQ
1	Phenobarbital	460	22
2	Sedatin	955	45
3	Lexotam	356	31
4	Valium	246	15
5	Rohypnol	100	9

DISCUSSION

Prediction results using the Monte Carlo method produce a difference between the predicted results and reality, as shown in Figure 1. To measure the difference, error measurement is used. For the record, random numbers are a significant influence on this prediction. Random numbers reflect drug needs that cannot be predicted at any time. Even though they represent unpredictable values, random numbers can produce high bias.

Table 7. Drug Supply Percent Error

No	Drug Name	Supply	Supply Prediction	Difference	Percent Error
1	Phenobarbital	8950	9760	810	9,05%
2	Sedatin	7598	7674	76	1,00%
3	Lexotam	4430	4654	224	5,06%
4	Valium	6520	6456	64	0,98%
5	Rohypnol	1530	1460	70	4,58%
Average		5806	6001	249	4,13%

The results of the errors found are shown in Table 7. The farthest distance reached 810 units, and the lowest distance was 64 units. The overall comparison of the distance between the actual value and the predicted value is shown as a Percent Error. The smaller the Percent Error, the higher the accuracy value. The accuracy value can be understood as the confidence value in the predictions produced. The average percent error obtained based on the data used was 4.13%, with a prediction difference of 249 drugs. These results also depend on the data used.

Table 8. Drug Demand Percent Error

No	Drug Name	Demand	Demand Prediction	Difference	Percent Error
1	Phenobarbital	615	460	155	25,20%
2	Sedatin	634	955	321	50,63%
3	Lexotam	412	356	56	13,59%
4	Valium	327	246	81	24,77%
5	Rohypnol	148	100	48	32,43%
Average		427	423	132	29,33%

Drug Demand data underwent the same treatment to compare prediction results with the Monte Carlo method. The distance between the actual drug demand value and the predicted results for the drug demand value is similar to the difference between the actual drug supply value and the predicted results for the drug supply value. A very high difference between the two data is found in the Percent Error. In Table 6, the lowest Percent Error is 13.59%, while the highest Percent Error in drug supply is 9.05%. The prediction results with the Monte Carlo Method also depend on the data used.

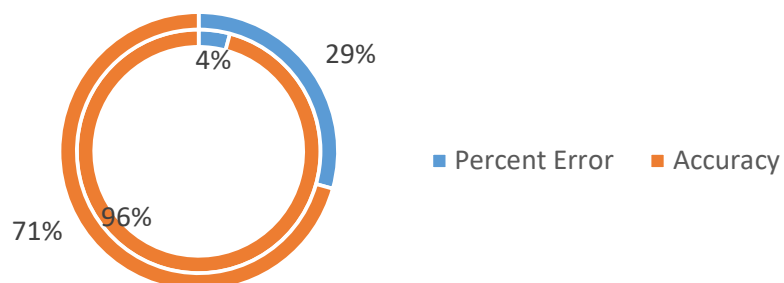


Figure 1. Differences of Accuracy and Percent Error for Supply and Demand Prediction Results

The dependence of the results on the data used is proven in the Percent Error results for drug demand data in Table 6. The average percent error value for drug demand obtained is much higher than that for drug supply data, as shown in Figure 1. The results of the observations found are a tendency for values to appear repeatedly according to the possibilities that could occur. Pay attention to Table 7 and Table 8. The closer the distance between the values for each row of data, it can be concluded that the lower the error that can be produced. Several alternatives to increase the accuracy value are increasing the variety of existing data and load values with data distance density for each row.

CONCLUSION

Psychotropic drugs are dangerous drugs and need to be controlled. Control is carried out to avoid protecting drugs other than for legal medical needs. Controlling the use of psychotropic drugs can be solved one way by supply and demand relationships. The availability of psychotropic drugs should be adjusted to needs or requests so that there are no drugs that are not used legally. The problem he knows is that the next request has not yet come, while the procurement of Psychotropic Drugs takes a long time.

The Monte Carlo simulation method predicts demand based on previously collected data patterns. The data used is supply and demand data for every month of one year. The results obtained are the probability of supply and demand for drugs each month, which can be used as a prediction for the coming months. The accuracy of using the Monte Carlo method for prediction depended on the data pattern used. Proven by supply accuracy of 4% and demand of 29%. Both are treated the same apart from the data usage. Data pattern observations were carried out to find the cause of the large difference in accuracy. It was found that the closer the distance between the data, the higher the prediction accuracy obtained. That is because the Monte Carlo method makes predictions based on the probability that it will happen again with the same value. The results of the predictions are then applied to the Economic Order Quantity (EOQ) Method. This method calculates how many drugs should be ordered based on predicted demand for the following year.

The recommendation for using data that is more detailed, large and has a dense distribution distance provides a high accuracy value for using the Monte Carlo method. Other forecasting methods such as Machine Learning and Business Intelligence can also make predictions. Further studies are needed to compare the accuracy of prediction results from other methods such as the Monte Carlo method, Machine Learning, and Business Intelligence.

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