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Forecasting of jansen's rice inventory control using monte carlo and markov chain techniques

Hasni Indah Sari[1], Sajaratud Dur[2], Hendra Cipta[3]

[1,2,3]Faculty of Science and Technology, Universitas Islam Negeri Sumatera Utara Medan, Indonesia

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ABSTRACT

Rice is an essential commodity in Indonesia because of its role as a staple food, which most Indonesians consume daily as a carbohydrate intake. In its development to meet these needs, many things affect the stability of the availability and price of this rice. They are starting from climatic conditions, logistics systems, and the state of the domestic market and the international rice market. On the other hand, the increase in national rice consumption from year to year will continue to grow along with the rise in population. This research aims to apply the Monte Carlo and Markov Chain method to control Jansen rice supplies at the Jansen Rice Mill, Paluh Wave Street, Percut Sei Tuan District, Deli Serdang Regency, North Sumatra Province. The data used is data on rice demand from 2016 to 2021. Monte Carlo forecasts for the next few years, and Markov Chain provides what percentage of opportunities for rice demand to increase or decrease.

Corresponding Author:

Hasni Indah Sari,
Faculty of Science and Technology,
Universitas Islam Negeri Sumatera Utara Medan,
Jl. William Iskandar Ps. V, Kabupaten Deli Serdang, Sumatera Utara 20371, Indonesia.
Email: hasniindahsari@gmail.com

1. INTRODUCTION

Rice is an essential commodity in Indonesia because of its role as a staple food, which most Indonesians consume daily as a carbohydrate intake[1]. Moreover, rice is also a dominant strategic commodity in the Indonesian economy because it is closely related to monetary policy and concerns socio-political problems[2].

Rice contributes to the country's food security, poverty, macroeconomic stability, and economic growth[3]. Considering that rice is a strategic and political commodity, as one of the domestic rice providers, the Jansen Rice Factory participates in fulfilling the availability of domestic rice[4], which must always be fulfilled. In its development to meet these needs, many things affect the stability of the availability and price of this rice[5]. They start from climatic conditions, logistics systems, and domestic and international rice market conditions[6]. On the other hand, the increase in national rice consumption from year to year will continue to grow along with the rise in the population[7]. Another challenge, according to, in increasing the availability of rice is the limited growth of harvested area because the increase in agricultural[8] harvested area is very limited considering a large number of conversions of agricultural land to non-agricultural land[9], degradation of water and irrigation resources, declining levels of soil fertility, and symptoms of a decline in rice production[10].

Inventory control is essential to ensure a company's smooth and continuous operation. In a trading company[11], inventory control ensures that the sales process is achieved optimally. Meanwhile[12], inventory control is needed in production companies to ensure the production process continues[13]. Inventory in the company, viewed from the financial aspect, is an element of working capital that will continuously rotate in the working capital turnover cycle[14]. Because it will directly impact capital turnover, inventory control will affect costs in the company[15]. Inventory or inventory is a technique related to determining the rice stock of materials that must be held to ensure the smooth running of production operations[16], as well as determining the procurement schedule and the number of orders for goods that should be made by the company[17].

The Monte Carlo simulation method is a simulation technique that uses random numbers to solve problems involving uncertainty states where mathematical evaluation is not possible[18]. The basis of the *Monte Carlo* simulation is the return of a random sample[19]. The construction of the *Monte Carlo method* is based on the probability obtained from historical data of an event and its frequency[20]. Markov chain is a mathematical technique commonly used to predict future changes in dynamic variables based on changes in the dynamic variables in the past[21]. This technique can also be used to analyze future events mathematically[22].

The Markov Chain Monte Carlo (MCMC) method has been widely applied to solve various problems[23]. In many fields of the applied sciences, inference from time-series data is an essential class of the issues[24]. A standard modelling approach is to develop a mechanical model (deterministic or stochastic) that captures the temporal dynamic of the target phenomenon and then optimizes the model parameters so that the theory and observation are consistent[25]. Markov Chain Monte Carlo is a widely used approach that can efficiently sample from high dimensional parameter space[26].

2. RESEARCH METHOD

At this stage, processing of the data obtained from the Jansen Rice Mill was carried out in the following stages: (1) Collecting data that will be used in research, namely Jansen rice inventory data[27]. (2) Identify the monthly data archive of rice production at the Jansen Rice refinery. (3) Calculates the frequency distribution, determines the range[28], the number of class intervals, and the length of the class (4) Creating a *Monte Carlo method model* based on the data variables formed[29].

$$Pi = \frac{fi}{n} \quad (1)$$

(5) Then using a random number generator

$$Z_i = (aZ_{i-1} + c)mod m \quad (2)$$

(3) The results can be calculated using the *Markov Chain method*, determine the probability matrix of n steps of transition, and then use the Chapman-Kolmogorov equation[30]. (4) Draw conclusions from the results obtained.

3. RESULTS AND DISCUSSIONS

3.1. Data Description

Suggests inventory is material or goods stored that will be used to meet specific goals, arguing that the message of inventory control is to minimize total inventory costs purposes. Data on the number of requests for rice at the Jansen P rice mill. The waves were obtained from two harvests a year, namely harvesting in October and March each year starting from October 2016 to March 2021, with a total amount of 889000 kg.

Table 1. Total Demand For Rice At The Jansen Paddy Refinery From October 2016-March 2021

No	Harvest Time	Total Demand for Rice (Kg)
1	Oct-16	87920
2	Mar-17	120680
3	Oct-17	106120
4	Mar-18	92400

No	Harvest Time	Total Demand for Rice (Kg)
5	Oct-18	90650
6	Mar-19	85750
7	Oct-19	87150
8	Mar-20	78260
9	Oct-20	73150
10	Mar-21	66920
	Total	889000

3.2 Estimation with Monte Carlo

1) Min and Max Value

Table 2. Determination Of Min And Max, Values

Min	66920
Max	120680

2) Frequency Distribution

Monte Carlo Sampling more strictly means the technique of choosing numbers randomly from a probability distribution to run a simulation. Compile a frequency distribution table with the same class length, and perform the following steps:

Step 1. Determine the Range (R) to determine the range that can be obtained from the result of subtracting the maximum and minimum values.

$$R = Maximum\ value - Minimum\ value \quad (3)$$
$$R = 120680 - 66920$$
$$R = 53760$$

Step 2. Determines the number of classes (K), Divides the partition of the range into parts with equal intervals (n).

$$k = 1 + 3{,}3 \log n \quad (4)$$
$$k = 1 + 3{,}3 log 10$$
$$k = 1 + 3{,}3(1)$$
$$k = 1 + 3{,}3$$
$$k = 4$$

Step 3. Determine the length of the class (C); based on the results above, the value of the length of the interval class and the range has been determined previously, the range will be partitioned into 4 intervals of the same length. Then find the length of the interval using the equation. The value of *c is obtained* as follows:

$$c = \frac{max - min}{k} \quad (5)$$
$$c = \frac{53760}{4} = 13440$$

From the calculation results above, the range of the difference between the maximum and minimum data is 53760. The number of interval classes is four intervals of the same length, and for the size of the interval class, the rending division is obtained with the number of intervals, namely 13440. The initial data starts from the minimum data. which is 66920 plus the length value of the interval class, which is 13440, then the first interval value is 66920-80360 with a mean value of 73640 and a frequency of 3, which is presented in table 3.

Table 3. *Relative* Frequency

Interval	Middle value	Frequency
66920-80360	73640	3
80361-93801	87081	5
93802-107242	100522	1
107243-120683	113963	1
Total		10

Maximizing the results of the calculation of the frequency distribution, the amount of rice demand that must be provided by the Jansen rice mill, the probability and cumulative probability must be determined first, Create a Monte Carlo simulation model based on the probability obtained from the previous data and its frequency using equation (1):

$$Pi = \frac{fi}{n} \tag{6}$$

$$P_1 = \frac{f_1}{n} = \frac{3}{10} = 0{,}3$$

$$P_2 = \frac{f_2}{n} = \frac{5}{10} = 0{,}5$$

$$P_3 = \frac{f_3}{n} = \frac{1}{10} = 0{,}1$$

$$P_4 = \frac{f_4}{n} = \frac{1}{10} = 0{,}1$$

The probability value of each event i has been obtained then for the first cumulative value is the total of the first probability $P_1$the second cumulative value is the total of the first probability plus the second probability $P_1 + P_2$ as well as for the next cumulative probability value as presented in table 4. Random numbers that appear variably are generated, then the probability that the level of occurrence of the generated random numbers will be related to the value of the random interval. So that the addition of random number intervals is seen from the cumulative value, whose value will be multiplied by 100.

Table 4. Cumulative Probability

Probability	Cumulative	Random Number Interval
0.3	0.3	0-30
0.5	0.8	31-80
0.1	0.9	81-90
0.1	1	91-100

3.3 Random Variable

Monte Carlo involves a random selection of each output repeatedly so that a solution with a particular approach is obtained. Generating random variable, random variables are arbitrary numbers and have criteria that must be met to generate random variables using the *Linear Congruent Method* (LCM). Requirements for generating random variable using the LCM method using equation (2):

1) The constant a must be greater than
2) For the constant c must be odd if m is a power of two. Cannot be multiples of m
3) For the modulus m must be a primary number or an undivided number.
4) To Z_i must be an integer number as well as odd and large enough.

Generate random numbers using the linear congruental method if it is known $Z_0 = 70$,c $= 49$, $a = 19$, and $m = 100$

Solution:

a. $Z_1 = (a.Z_0 + c)\text{mod}m$ (7)

$Z_1 = (19)(88) + (49)\text{mod}100$

$Z_1 = (1672 + 49)\text{mod}100$

$Z_1 = (1721)\text{mod}100$

$Z_1 = 21$

b. $Z_2 = (a.Z_1 + c)\text{mod}m$ (8)

$Z_2 = (19)(79) + (49)\text{mod}100$

$Z_2 = (1501 + 49)\text{mod}100$

$Z_2 = (1550)\text{mod}100$

$Z_2 = 50$

c. $Z_3 = (a.Z_2 + c)\text{mod}m$ (9)

$Z_3 = (19)(6) + (49)\text{mod}100$

$Z_3 = (114 + 49)\text{mod}100$
$Z_3 = (163)\text{mod}100 Z_3 = 63$

d. $Z_4 = (a.Z_3 + c)\text{mod}m$ (10)
$Z_4 = (19)(56) + (49)\text{mod}100$
$Z_4 = (1064 + 49)\text{mod}100$
$Z_4 = (1113)\text{mod}100$
$Z_4 = 13$

e. $Z_5 = (a.Z_4 + c)\text{mod}m$ (11)
$Z_5 = (19)(13) + (49)\text{mod}100$
$Z_5 = (274 + 49)\text{mod}100$
$Z_5 = (296)\text{mod}100$
$Z_5 = 96$

f. $Z_6 = (a.Z_5 + c)\text{mod}m$ (12)
$Z_6 = (19)(85) + (49)\text{mod}100$
$Z_6 = (1615 + 49)\text{mod}100$
$Z_6 = (1664)\text{mod}100$
$Z_6 = 64$

g. $Z_7 = (a.Z_6 + c)\text{mod}m$ (13)
$Z_7 = (19)(94) + (49)\text{mod}100$
$Z_7 = (1786 + 49)\text{mod}100$
$Z_7 = (1835)\text{mod}100$
$Z_7 = 35$

h. $Z_8 = (a.Z_7 + c)\text{mod}m$ (14)
$Z_8 = (19)(74) + (49)\text{mod}100$
$Z_8 = (1406 + 49)\text{mod}100$
$Z_8 = (1455)\text{mod}100$
$Z_8 = 72$

i. $Z_9 = (a.Z_8 + c)\text{mod}m$ (15)
$Z_9 = (19)(20) + (49)\text{mod}100$
$Z_9 = (380 + 49)\text{mod}100$
$Z_9 = (429)\text{mod}100$
$Z_9 = 29$

j. $Z_{10} = (a.Z_9 + c)\text{mod}m$ (16)
$Z_{10} = (19)(40) + (49)\text{mod}100$
$Z_{10} = (760 + 49)\text{mod}100$
$Z_{10} = (809)\text{mod}100$
$Z_{10} = 9$

Seek to fulfill this theory wirh their Monte Carlo type map simulation algorithms [20],[21]. Both algorithms begin with a randomly selected unit. Both then build on to the randomly selected unit by merging another randomly selected unit on the border of that unit. The results of the calculation of random values from Z_1 up to Z_{10} have been obtained with the above calculations, the estimation results to find out the next rice supply using Monte Carlo simulations are obtained from random numbers that have been generated from the above method. Based on table 4, the median value of each of these random values is determined, the first random number value Z_1 is 21 where the number 21 in the first random number interval then the value taken for the Monte Carlo value is the middle value where the middle value for the number 21 is 73640 as well as further until Z_{10} presented in table 5.

Table 5. Estimated rice inventory using monte carlo with random value

Harvest Time	Random Value	Middle value
Oct-21	21	73640
Mar-22	50	87081

Harvest Time	Random Value	Middle value
Oct-22	63	87081
Mar-23	13	73640
Oct-23	96	113963
Mar-24	64	87081
Oct-24	35	87081
Mar-25	55	87081
Oct-25	29	73640
Mar-26	9	73640
Total		843928

3.4 Markov Chain

Data on the number of requests for rice at the Jansen P rice mill. The wave obtained from two harvests in a year, namely harvesting in October and March each year starting from October 2016 to March 2021 with a total amount of 889000 kg.

Table 6. Total Rice Demand at the Jansen Rice Refinery from October 2016-March 2021

Harvest Time	Number of Rice Requests (kg)
Oct-16	87920
Mar-17	120680
Oct-17	106120
Mar-18	92400
Oct-18	90650
Mar-19	85750
Oct-19	87150
Mar-20	78260
Oct-20	73150
Mar-21	66920
Total	889000

The transition probability matrix is a matrix that provides information that governs the system's movement from one state to another. The demand for rice in each harvest period has increased and decreased. Based on the data above, it can be seen that there is an increase and decrease in the number of requests for rice, so from the data it can be classified into 2 states where there is an up and down state.

Table 7. State Transition Amount Of Rice Demand

Harvest Period	Number of Rice Requests (kg)
Oct-21	-
Mar-22	Up
Oct-22	Down
Mar-23	Down
Oct-23	Down
Mar-24	Down
Oct-24	Up
Mar-25	Down
Oct-25	Down
Mar-26	Down

Based on table 7 above, it is obtained that state transitions that occur in each harvest period are grouped into two, namely $K = \{K_1, K_2\}$ where K_1 = up and K_2 = down. Then obtained the transition probability matrix of the state transition from the table above is presented in table 8.

Table 8. Transition Probability Matrix

Initial state	Final state	
	1	2
1	5	2
2	2	0

The frequency of rice demand *state transition* can then be formed into a matrix as follows [23], [24],

$$P = \begin{bmatrix} 5 & 2 \\ 2 & 0 \end{bmatrix}$$

by obtaining the state transition matrix of rice demand, it can be calculated the percentage value of each state:

$$P = \begin{bmatrix} \frac{5}{7} & \frac{2}{7} \\ \frac{2}{2} & \frac{0}{2} \end{bmatrix} = \begin{bmatrix} 0{,}714 & 0{,}286 \\ 1 & 0 \end{bmatrix}$$

By using the Chapman-Kolmogrov equation where $P^n = P^{(n-1)}.P$, which $P^n$is obtained by raising the probability matrix of the transition one step Pabove by as many $n$times, where $n = 1,2,3,\dots,n$. In the previous step, the one-step transition opportunity matrix for crude oil exports was obtained as follows.

$$P = \begin{bmatrix} 0{,}714 & 0{,}286 \\ 1 & 0 \end{bmatrix}$$

Then the probability matrix of the transition to $n$from $P^{(n)}$is as follows:

$$P^2 = P\ x\ P$$
$$P^2 = \begin{bmatrix} 0{,}796 & 0{,}204 \\ 0{,}714 & 0{,}286 \end{bmatrix}$$
$$P^3 = P^2\ x\ P$$
$$P^3 = \begin{bmatrix} 0{,}772 & 0{,}228 \\ 0{,}796 & 0{,}204 \end{bmatrix}$$
$$P^4 = P^3\ x\ P$$
$$P^4 = \begin{bmatrix} 0{,}779 & 0{,}221 \\ 0{,}772 & 0{,}228 \end{bmatrix}$$
$$P^5 = P^4\ x\ P$$
$$P^5 = \begin{bmatrix} 0{,}777 & 0{,}223 \\ 0{,}779 & 0{,}221 \end{bmatrix}$$
$$P^6 = P^5\ x\ P$$
$$P^6 = \begin{bmatrix} 0{,}778 & 0{,}222 \\ 0{,}777 & 0{,}223 \end{bmatrix}$$
$$P^7 = P^6\ x\ P$$
$$P^7 = \begin{bmatrix} 0{,}78 & 0{,}22 \\ 0{,}78 & 0{,}22 \end{bmatrix}$$

State probability in the future, by knowing the one-step transition matrix Pand the probability vector at the beginning of the process, it is possible to predict the change vector p^0 for each state export and import value by using:

$$p^n = p^{n-1}P, n = 1,2,3, \dots, k \quad (17)$$

The probability *state* at the start of the process is

$$p^0 = [p_1^0, p_2^0] \quad (18)$$

Value p_i^0, $i = 1,2,\dots$is the probability of demand for rice in an up and down state. p_1^0 obtained from the number of requests in a state of increasing, divided by the number of requests for rice. p_2^0 obtained from the number of requests in a state of decline, divided by the number of requests for rice. The probability of the demand *state* for rice at the beginning of the process is $p^0 = [0{,}78\ \ 0{,}22]$ then obtained:

$$p^1 = p_1^0 P$$
$$p^1 = [0{,}78\ \ 0{,}22] \begin{bmatrix} 0{,}714 & 0{,}286 \\ 1 & 0 \end{bmatrix}$$
$$p^1 = [0{,}55692 + 0{,}22\ \ 0{,}22308 + 0]$$
$$p^1 = [0{,}77692\ \ 0{,}22308]$$
$$p^2 = p^1 P$$
$$p^2 = [0{,}77692\ \ 0{,}22308] \begin{bmatrix} 0{,}714 & 0{,}286 \\ 1 & 0 \end{bmatrix}$$
$$p^2 = [0{,}7778\ \ 0{,}2222]$$

$$p^3 = p^2 P$$
$$p^3 = [0{,}7778\ \ 0{,}2222]\begin{bmatrix}0{,}714 & 0{,}286\\ 1 & 0\end{bmatrix}$$
$$p^3 = [0{,}77755\ 0{,}2245]$$
$$p^4 = p^3 P$$
$$p^4 = [0{,}77755\ 0{,}2245]\begin{bmatrix}0{,}714 & 0{,}285\\ 1 & 0\end{bmatrix}$$
$$p^4 = [0{,}77762\ \ 0{,}22238]$$
$$p^5 = p^4 P$$
$$p^5 = [0{,}77762\ \ 0{,}22238]\begin{bmatrix}0{,}714 & 0{,}285\\ 1 & 0\end{bmatrix}$$
$$p^5 = [0{,}7776\ \ 0{,}2224]$$
$$p^6 = p^5 P$$
$$p^6 = [0{,}7776\ \ 0{,}2224]\begin{bmatrix}0{,}714 & 0{,}285\\ 1 & 0\end{bmatrix}$$
$$p^6 = [0{,}77761\ \ 0{,}22239]$$
$$p^7 = p^6 P$$
$$p^7 = [0{,}77761\ \ 0{,}22239]\begin{bmatrix}0{,}714 & 0{,}285\\ 1 & 0\end{bmatrix}$$
$$p^7 = [0{,}7776\ \ 0{,}2224]$$
$$p^7 = [0{,}78\ \ 0{,}22]$$

Analysis of the probability *state* of demand for rice at the Jansen Rice Mill. The probability of transition at a balanced state level is the opportunity for a transition that has reached equilibrium, so it will not change with changes in time that occur or changes in stages that occur. Calculating the *state probabilities of n* steps will provide important information about *state* probabilities as presented in table 9.

Table 9. Opportunity of rice demand state

	Opportunity State *n* Steps						
State	p^1	p^2	p^3	p^4	p^5	p^6	p^7
State 1	0.777	0.777	0.778	0.778	0.778	0.778	0.778
State 2	0.22	0.223	0.222	0.222	0.222	0.222	0.222

Based on table 9 it can be seen that each of the above *state vectors* converges to a fixed vector. The probability of demand for rice in a state of increasing is 78% and the probability of demand for rice in a state of decreasing is 22%. After observing and understanding the uncertainty of rising and falling demand for rice, as well as using some assumptions, the Markov Chain model fits the data studied. Data obtained from the calculation results of each increase and decrease in rice demand at the Jansen Rice.

Table 10. Prediction of Rice Demand Opportunities

State	Rice Request
Go on	78%
Down	22%

4. CONCLUSION

The forecasting using the Monte Carlo method provides forecasts for October 2021 to March 2026 with a total forecast of rice demand of 843928 kg. The method of the Markov Chain generates a 78% chance that the demand for rice will increase and the demand will decrease by 22%.

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