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Implementation of Markov Chain on MSME Data for QRIS Users in Medan City

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A B S T R A C T

QRIS (Quick Response Indonesian Standard) is a non-cash payment system innovation initiated by Bank Indonesia in collaboration with the Indonesian Payment System Association. This is one response to the era of digitalization and industry 4.0. Since January 2020, Bank Indonesia has required (implemented) QRIS for non-cash payments, especially for micro, small and medium enterprises (SMEs), because it is a sector that contributes to Gross Domestic Product. Therefore, this study is intended to predict the number of SMEs using QRIS in Medan in the future based on the Markov Chain method. The data used is the number of MSMEs that use QRIS as a cashless payment in Medan City from Bank Indonesia North Sumatra in December 2019 to June 2022. The results show that there is a balance in October 2022 with a 52.2% chance percentage with declining conditions; 30.4% with an increasing condition, and 8.7% with a strongly increasing and decreasing condition. This good accuracy is checked with Mean Absolute Percentage Error (MAPE).

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INTRODUCTION

In line with economic developments and changes, the use of digital technology or known as economic digitization has also increased. The development of the digital economy that occurred in Indonesia in October 2019 had reached USD 40 billion or IDR 556.6 trillion. growth in the digital economy sector in Indonesia is much helped by *e-commerce* which is growing very fast [1]. The impact resulting from the acceleration of economic digitization will greatly affect the economic welfare of the community.

Based on research data conducted by [1] it is known that the increase in Indonesia's digital economic growth is strongly influenced by *a lot of e-commerce* in Indonesia. The situation prompted Bank Indonesia to improve the payment system with the launch of the *Quick Response Code Indonesia Standard* (QRIS) [2]. QRIS is the unification of various *QR codes* from various Payment System Service Providers (PJSP) using a *QR Code* , *launched* on August 17, 2019 QRIS is a new program initiated by Bank Indonesia in collaboration with the Indonesian Payment System Association (ASPI) as a form of digital payment transformation. In the QRIS program as of January 1, 2020, it is mandatory for all *merchants* , namely product/service sellers who accept payments via *e-money* [2].

The first application of QRIS is for MSME traders [3]. The number of MSMEs in 2021 will reach 64.2 million with a contribution to GDP (Gross Domestic Product) of 61.07% or worth 8,573.89 trillion rupiah, the data provides a statement [4] where MSMEs have great potential in providing a role for the economy . With the collaboration between MSMEs and electronic money providers, it will improve finances, including advancing the Indonesian economy [3]. For that, we need to see to what extent this QRIS is realized through data on MSMEs that have used QRIS in their transactions. The more MSMEs that use QRIS, the objectives of standardizing payments by Bank Indonesia and increasing financial inclusion in Indonesia can be realized.

The data of MSME users who use QRIS in their transactions in the future is related to the extent to which QRIS data users are today. Because based on the QRIS guidelines, a QRIS user only has 1 QRIS account, in other words, there are no double-registered accounts. With the new habit of making non-cash transactions by customers, the use of QRIS has increased. So they don't want economic actors, one of which is MSMEs, to provide efficient non-cash payments, namely QRIS. This condition meets the requirements of the *Markovian Property* , which states that the conditional probability of a future event depends only on the present state and does not depend on the previous state. Markov chain was developed by a Russian expert named AA Markov in 1896. In the analysis of Markov chain the resulting probabilistic information that can be used in decision making. This technique can be used to predict future time changes in dynamic variables on the basis of changes in these variables in the past [5].

In this study, it will be seen how the implementation of QRIS on MSMEs in the city of Medan will be made where predictions will be made to obtain probabilistic information for each period based on an analysis of factual data obtained from Bank Indonesia. The data used to fulfill the stochastic process, namely the data changes over time. In accordance with Markov's nature, current conditions contain relevant information to predict future conditions in a probabilistic sense, and past conditions only affect current conditions. Where in probabilistic, if the probability value of the event is close to 1, then the probability of the event occurring in the future will be even greater [7].

This study aims to see the extent to which the QRIS policy has been implemented through data on MSMEs using QRIS in the city of Medan through predictions of MSME data using QRIS users in Medan in the future with the hope that the results can be used by economic actors and other government agencies to optimize efforts to digitize the economy through non-cash payment transactions, namely QRIS. This is in line with the efforts made by Bank Indonesia to respond to challenges in the digital era and *industry* 4.0, namely the Indonesian Payment System *Blueprint (BSPI) 2025 [8].*

IMPLEMENTATION AND METHODS

Research data

The data used in this study is data on the increase in the number of MSMEs in the city of Medan using QRIS for the period December 2019-June 2022. Data obtained from the Bank Indonesia Representative Office, North Sumatra.

Research Stages

R programming language assistance . Some of the steps taken in implementing Markov Chain on MSME data for QRIS Users in Medan City are as follows:

1. Collecting research data sourced from the Representative Office of Bank Indonesia North Sumatra for the period December 2019-June 2022.
2. to analyze categorical data and then determine the interval in each category by finding the average and finding the maximum and minimum values for each category.
3. Analyze the data according to the research. The situation in the data movement, download download song download song download download song download song download download download song download song download song download download song download song download song download download song download song download download song k_{ij} *download download* download *song* download song

$$K = \begin{bmatrix} k_{00} & k_{01} & \cdots & k_{0m} \\ k_{10} & k_{11} & \cdots & k_{0m} \\ \vdots & \vdots & \vdots & \vdots \\ k_{m0} & k_{m0} & \cdots & k_{mm} \end{bmatrix} \quad (1)$$

Where k_{ij} = number of songs *i* to *state j* safe process.

4. Forming the Transition Probability Matrix, the matrix P is called the one-step transition probability matrix or abbreviated as the transition probability matrix. When S finite, let's say $S = \{1,2,...,m\}$ it can be represented P as follows [6]:

$$P = \begin{bmatrix} p_{1.1} & p_{1.2} & \cdots & p_{1.m} \\ p_{2.1} & p_{2.2} & \cdots & p_{2.m} \\ \vdots & \vdots & \ddots & \vdots \\ p_{m.1} & p_{m.2} & \cdots & p_{m.m} \end{bmatrix} \quad (2)$$

where $p_{ij} \geq 0$ and $\sum_{j=0}^{\infty} p_{ij} = 1; i, j = 0,1,2,...,m$

5. Determine the Step-Transition Probability Matrix. A step transition probability matrix n satisfies the Chapman-Kolmogorov equation Chapman-Kolmogorov equation in matrix form [9],

$$p^{(m+l)} = p^{(m)} * p^{(l)} \quad (3)$$

The n-step Transition Probability Matrix is obtained by multiplication between matrices, where $p^{(m+l)}$ is the n-step transition probability matrix, $p^{(m)}$ is the transition probability matrix, and $p^{(l)}$ is the lth time matrix .

6. Predict the probability of the data in the future until it reaches a *steady state.* Obtained by the following equation ,

$$Q(n+1) = P^T q(n) \quad (4)$$

Where $Q(n+1)$ is the probability prediction of the data, P^T is the transition matrix with the power of the forecast period and $q(n)$ is the condition of the data at time *n.* Fixed-State Probability (*Steady-State Probability*) can change with the opportunities in every situation will not pass time. This shows that after the process has been running for several periods, the opportunity value will be stable in the long term.

7. Test the accuracy of predictive data. *Mean Absolute Percentage Error* (MAPE) is the average value of the absolute difference that exists between the predicted value and the realized value stated as a percentage of realization, with the formula [10]:

$$MAPE = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{A_i - F_i}{A_i} \right| \times 100\% \quad (5)$$

Where *n* is the sample size , A_i is the actual data value and F_i is the forecast data value.

8. Conclusions are drawn by presenting data predictions until they reach a *steady state* supported by the accuracy test of the research.

RESULTS AND DISCUSSION

Research data

Data obtained from Bank Indonesia is an accumulation of the number of MSMEs consisting of the Medium, Small and Micro categories from period to period. The policy on using QRIS for MSMEs has been set since December 2019 and implemented nationally as of January 2020, therefore in this study the data used for the period December 2019 to June 2022. However, in this case, the data used to predict is the data for the period December 2019 to December 2021. , and the data for the period January 2022 to June 2022 will be used as actual data in the process of testing the accuracy of the predictions.

Table 1. Data for SMEs QRS Users in Medan City

year	Period	amount	Difference
2019	December	36,330	36,330
	January	62.048	25,718
	February	66,912	4,864
	March	75,324	8.412
	April	81,554	6.230
	May	86.999	5.445
2020	June	91.393	4.394
	July	99,274	7,881
	August	106,417	7.143
	September	113.389	6,972
	October	118,972	5.583
	November	126.515	7.543
	December	133,301	6.786
	January	139,087	5.786
	February	144,513	5.426
	March	150,815	6,302
	April	159,437	8,622
	May	165,836	6,399
2021	June	175.265	9,429
	July	187,406	12,141
	August	207,754	20,348
	September	225,661	17.907
	October	241.305	15,644
	November	265.535	24,230
	December	283.490	17,955

Based on this, the data can be classified into 4 conditions , *namely* drastically up, up, down, down drastically. The data is classified into 4 conditions because the data conditions have increased and decreased significantly. Therefore an interval

is formed for each state. For the rising category, all data experienced an average increase of 3,858,444 with the highest data increase of 8,586. For the declining category, all data that has decreased has an average of -3,540.07 with the highest data decline of -20,854. Based on this, the following 4 state intervals will be used,

State 1 = **Increase** with interval $[0 \le x < 3.858,444]$

State 2 = **Increases Drastically** with interval $[3.858,444 \le x \le 8.586]$

State 3 = **Decrease** with interval $[-3.540,07 \le x < 0]$

State 4 = **Drops Drastically** with interval $[-20.854 \le x < -3.540,07]$

Transition Opportunity Matrix

The following is the data changes or songs from the QRIS MSME data in the city of Medan:

Table 2. Transfer *of State Data for* MSMEs QRIS Medan City

year	Period	amount	Difference	Transitional State
2019	December	36,330	36,330	
2020	January	62.048	25,718	Drastic Drop
	February	66,912	4,864	Drastic Drop
	March	75,324	8.412	Go on
	April	81,554	6.230	Down
	May	86.999	5.445	Down
	June	91.393	4.394	Down
	July	99,274	7,881	Go on
	August	106,417	7.143	Down
	September	113.389	6,972	Down
	October	118,972	5.583	Down
	November	126.515	7.543	Go on
	December	133,301	6.786	Down
2021	January	139,087	5.786	Down
	February	144,513	5.426	Down
	March	150,815	6,302	Go on
	April	159,437	8,622	Go on
	May	165,836	6,399	Down
	June	175.265	9,429	Go on
	July	187,406	12,141	Go on
	August	207,754	20,348	Drastic Rise
	September	225,661	17.907	Down
	October	241.305	15,644	Down
	November	265.535	24,230	Drastic Rise
	December	283.490	17,955	Drastic Drop

Based on Table 2, it is found that there is a state in each period and can be increased by four, namely: $P = \{P_1, P_2, P_3, P_4\}$ where P_1 = increases P_2 drastically, P_3 = decreases, P_4 = decreases drastically. The frequency of the QRIS MSME Data can be seen in the following matrix

$$p = \begin{bmatrix} 2 & 1 & 4 & 0 \\ 0 & 0 & 1 & 1 \\ 4 & 1 & 7 & 0 \\ 1 & 0 & 0 & 1 \end{bmatrix}$$

Dividing each matrix member by the number of data entries, the transition probability matrix is obtained:

$$P = \begin{bmatrix} 0,286 & 0,143 & 0,571 & 0 \\ 0 & 0 & 0,5 & 0,5 \\ 0,333 & 0,083 & 0,584 & 0 \\ 0,5 & 0 & 0 & 0,5 \end{bmatrix}$$

After obtaining the Transition Probability Matrix, then using the Chapman-Kolmorov equation to obtain an n-step Transition Probability Matrix. The n-step Transition Probability Matrix is obtained by multiplying between matrices as follows ,

$$P = \begin{bmatrix} 0,286 & 0,143 & 0,571 & 0 \\ 0 & 0 & 0,5 & 0,5 \\ 0,333 & 0,083 & 0,584 & 0 \\ 0,5 & 0 & 0 & 0,5 \end{bmatrix}$$

$$P^2 = P \times P$$

$$P^2 = \begin{bmatrix} 0,272 & 0,088 & 0,568 & 0,072 \\ 0,416 & 0,042 & 0,292 & 0,25 \\ 0,29 & 0,096 & 0,573 & 0,042 \\ 0,393 & 0,072 & 0,286 & 0,25 \end{bmatrix}$$

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$$P^{11} = P^{10} \times P$$

$$P^{11} = \begin{bmatrix} 0,304 & 0,087 & 0,522 & 0,087 \\ 0,304 & 0,087 & 0,522 & 0,087 \\ 0,304 & 0,087 & 0,552 & 0,087 \\ 0,304 & 0,087 & 0,552 & 0,087 \end{bmatrix}$$

Prediction in the future until it reaches a steady state

QRIS in MSMEs in Medan City is required by Bank Indonesia in December 2019. Therefore, the following initial conditions are used:

$$p^0 = \begin{bmatrix} 0 & 1 & 0 & 0 \end{bmatrix}$$

The calculation of the prediction of the Medan city QRIS SMEs in the future is as follows:

$$p^1 = \begin{bmatrix} 0 & 1 & 0 & 0 \end{bmatrix} * \begin{bmatrix} 0,286 & 0,143 & 0,571 & 0 \\ 0 & 0 & 0,5 & 0,5 \\ 0,333 & 0,083 & 0,584 & 0 \\ 0,5 & 0 & 0 & 0,5 \end{bmatrix}$$

$$p^1 = \begin{bmatrix} 0 & 0 & 0,5 & 0,5 \end{bmatrix}$$

$$p^2 = \begin{bmatrix} 0 & 0 & 0,5 & 0,5 \end{bmatrix} * \begin{bmatrix} 0,286 & 0,143 & 0,571 & 0 \\ 0 & 0 & 0,5 & 0,5 \\ 0,333 & 0,083 & 0,584 & 0 \\ 0,5 & 0 & 0 & 0,5 \end{bmatrix}$$

$$p^2 = \begin{bmatrix} 0,4165 & 0,0415 & 0,292 & 0,25 \end{bmatrix}$$

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$$p^{10} = \begin{bmatrix} 0,304 & 0,087 & 0,522 & 0,087 \end{bmatrix} * \begin{bmatrix} 0,286 & 0,143 & 0,571 & 0 \\ 0 & 0 & 0,5 & 0,5 \\ 0,333 & 0,083 & 0,584 & 0 \\ 0,5 & 0 & 0 & 0,5 \end{bmatrix}$$

$$p^{10} = \begin{bmatrix} 0,304 & 0,087 & 0,522 & 0,087 \end{bmatrix}$$

$$p^{11} = \begin{bmatrix} 0,304 & 0,087 & 0,522 & 0,087 \end{bmatrix} * \begin{bmatrix} 0,286 & 0,143 & 0,571 & 0 \\ 0 & 0 & 0,5 & 0,5 \\ 0,333 & 0,083 & 0,584 & 0 \\ 0,5 & 0 & 0 & 0,5 \end{bmatrix}$$

$$p^{11} = \begin{bmatrix} 0,304 & 0,087 & 0,522 & 0,087 \end{bmatrix}$$

Or it can be presented as follows,

Table 3. Prediction of QRIS MSME Data in Medan City

Country	*State 1*	*state 2*	*Country 3*	*state 4*
p^0	0	1	0	0
p^1	0	0	0.5	0.5
p^2	0.417	0.042	0.292	0.250
p^3	0.341	0.084	0.429	0.146
p^4	0.313	0.084	0.487	0.115
p^5	0.309	0.085	0.506	0.100
p^6	0.307	0.086	0.515	0.092
p^7	0.305	0.087	0.519	0.089
p^8	0.304	0.087	0.521	0.088
p^9	0.304	0.087	0.521	0.087
p^{10}	0.304	0.087	0.522	0.087
p^{11}	0.304	0.087	0.522	0.087

The probability at the equilibrium state level or *steady* probability is the probability that it has reached equilibrium, so it will not change the changes that occur or changes in the stages that occur. With the *country* 's potential This step will provide important information about the *n steady state* probability value of a system. Based on the table above, it can be seen that each vector *represents* the MSME QRIS value in the city of Medan above which it converges to a fixed vector. MSME data QRIS users in Medan City experienced *steady state conditions* in the 10th period. So if a simulation is carried out for the 11th period and so on, the chances will be the same as the 10th period.

Then it is known that,

1. The Opportunity for the Medan City QRIS MSME Value to be in a Drastic Increase is 8.7%
2. The opportunity for the Medan city QRIS value of SMEs to be in a state of increasing is 30.4%
3. Opportunity for the Medan City QRIS MSME Value to be in a Downturn is 52.2%
4. The Opportunity for the Medan City QRIS MSME Value to be in a Drastic Drop is 8.7%

Prediction Accuracy Test

In doing a forecast, the accuracy of the forecast is very important so that the forecast can be used in everyday life. To test the accuracy of predictions in this study, the MAPE (

Mean Absolute Percentage Error) test was used . it can be seen that in December there were 17,955 MSMEs in the city of Medan that used QRIS. It is assumed that the Prediction Data is at a predetermined interval at the beginning of the study by maintaining the position of the data position. By using equation (5) it is obtained,

Table 4. Prediction Accuracy Test

PERIOD	ACTUAL DATA		DATA PREDICTION		Absolute Error Value Divided by Actual Value
	amount	Condition	amount	Condition	
January	6,977	Dropped Drastically	8,968	Dropped Drastically	0.28537
February	9,269	Go on	9,896	Go on	0.06764
March	26,682	Drastic Rise	11.993	Down	0.550521
April	17,957	Dropped Drastically	10.888	Down	0.393663
May	15,072	Down	9.973	Down	0.338309
June	10,406	Dropped Drastically	7,978	Down	0.233327
MAPE TEST					19,380

Based on the results of the prediction accuracy test using the MAPE test, the prediction accuracy value is 19.38%. According to the rules of the MAPE test in Table 4, the accuracy of the predictions made in the study is in the Good category.

CONCLUSION

The results showed that predictions from the data on the number of QRIS users (*Quick Response Code Indonesian Standard)* by MSMEs (Micro, Small and Medium Enterprises) in the city of Medan changed each period, predictions for each period were obtained by multiplying the transition matrix for the forecast period with the conditions data in time to n. Based on *steady state predictions* , after the 10th period onwards the probability of the data will be in a stable condition where the number of QRIS user data by MSMEs in the city of Medan will be in a "Down" condition with a 52.2% chance. The accuracy of the data prediction using the MAPE test (*Mean Absolute Percentage Error)* is in the good category with a MAPE value of 19.38%.

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