Analysis of Changes in The Level of Social Restrictions Implemented by The Government of Indonesia with The Case Studies in East Java Province to Reduce The Spread of Covid-19

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Abstract: *The Coronavirus Disease 2019 (Covid-19) pandemic has hit Indonesia since March 2020. East Java Province contributed the fourth-highest number of patients from the start of the pandemic to February 2022. To combat the spread of the virus, the Indonesian government started to implement four-level Community Activity Restrictions or abbreviated as PPKM on July 26, 2021. According to the policy, the government will continue to enforce PPKM as long as the pandemic is still ongoing. To determine the level of PPKM in a region, conducting a study in that region is necessary and one way to do that is by doing an epidemiological study based on a statistical approach. Stochastic models based on the Markov Chain can be used as a statistical approach. This approach has the advantage that it can be used in modeling uncertain conditions based on certain states. The data used in this study is PPKM level shift every 1 – 2 weeks from 38 regencies and cities in East Java Province for the period July 26 – November 29, 2021. The data is sourced from the Instruction of the Minister of Home Affairs (Inmendagri). The results obtained are that currently PPKM level one has the highest probability of occurring in a sustainable manner, while level four has the lowest probability of occurring in East Java. The results of this study can be used as information for the people of East Java Province in preparing various adjustments to activities at the PPKM level set by the government.*

Keywords—Covid-19; stochastic model; PPKM; East Java Province; Markov chain

1. INTRODUCTION

Coronavirus Disease 2019 (Covid-19) pandemic is still a threat and a challenge for various countries in the world, including Indonesia. Since the first case appeared in Indonesia in early March 2020 until the number of cases continued to spike sharply, currently new positive cases of COVID-19 in various regions in Indonesia have not subsided and continue to appear. Until February 11, 2022, the number of positive cases in Indonesia reached 4,667,554 cases. East Java Province contributed the fourth-highest number of patients after Central Java starting from the beginning of the pandemic until February 2022 and the case was in the national spotlight in August 2021. As a province that is in fourth place, East Java Province actually contributed the second-highest death toll after Central Java Province, with 29,805 deaths [1].

The government has implemented many policies related to social restrictions in the community to overcome the increasingly massive spread of COVID-19 [2]. The social restriction policy began on March 31, 2020, the President of Indonesia, Joko Widodo signed Government Regulation No. 21 of 2020 which regulates large-scale social restrictions in response to COVID-19, which allows local governments to restrict the movement of people and goods in and out of the

country of their respective regions, unless they have obtained permission from the relevant ministry [3]. As of April 2020, the government has implemented many social restrictions with at least seven different terms. Starting from the Large-Scale Social Restrictions or abbreviated as PSBB, which took effect on April 17, 2020, to the latest, namely the Implementation of Restrictions on Community Activities or abbreviated as PPKM at four levels on July 26, 2021 [4]. The four-level PPKM policy that was set was based on the consideration that an adaptive and dynamic strategy was needed, adapted to the development of the epidemiology or the level of transmission of Covid-19 and the regional response capacity. The indicator of the level or transmission level of an area is divided into four levels based on three main indicators, one of which is the indicator of new confirmed cases per 100,000 population per week [5]. Unfortunately, the PPKM policy set by the government has a major impact on the economic aspect. Restrictions on community mobility, reduced operating hours of markets and other business places, and road blockades by security forces have hampered economic and social activities. According to the Ministry of Manpower, around 85% of workers were laid off because the company or office they worked for was not operating due to the implementation of PPKM. The majority of laid-off workers work in tourism, transportation, Micro, Small, and

Medium Enterprises or abbreviated as UMKM and manufacturing [6].

Pandemic to the epidemic is a term from epidemiology. Epidemiology is the study of the pattern of spread of disease or health-related events, as well as the factors that can influence these events [7]. Mathematical modeling of the pattern of disease spread in epidemiology needs to consider the element of uncertainty by constructing it in a stochastic model. One of the stochastic models that can be used in modeling these uncertain conditions is the Markov chain model [8]. The basic concept of Markov analysis is the state of the system or transition state. The nature of this process is that if it is known that the process is in a certain state, then the opportunity for the development of the process in the future only depends on the current state and does not depend on the previous state [9].

A previous study related to epidemiological studies using Markov chains was conducted by Aritonang et al. [10] with the title "Analysis of the Increase in Covid-19 Patients in Indonesia Using the Markov Chain Method". The article describes the long-term probability of Covid-19 patients in Indonesia in the period 19 March 2020 to 31 May 2020, where the state describes the range of the number of patients. In order to develop research in the field of epidemiology using the Markov chain method, the author analyzed one of the Indonesian government's policies in dealing with the spread of the Covid-19 virus, namely the shift of PPKM level and looked for long-term probabilities. This research is useful in making decisions by the government regarding the sustainability of community activities in various ways, especially in terms of the economy.

The PPKM level continues to shift due to many factors in various regions in Indonesia, including East Java Province. Apart from being known to be one of the provinces contributing to the highest number of positive cases, East Java Province is also known to have the widest area among the provinces on the island of Java and its population is the second largest in Indonesia in 2020 [11]. So, with the social restrictions or PPKM as well as the transfer of levels, of course, many people will be affected. Therefore, the authors conducted an analysis of the displacement of the PPKM level in East Java Province with the aim of knowing the level of PPKM in East Java in the long term or commonly referred to as the steady-state. This research is expected to be information or insight for the people of East Java to find out the probability of the PPKM level in their area so that they can better prepare themselves to minimize the impact of the PPKM. In addition, it is also hoped that it can become a recommendation for the government regarding policies that can be set so that the current pandemic condition can recover quickly and there will be no sudden spike in positive cases.

2. LITERATURE REVIEW

2.1 Enforcement of Restrictions on Community Activities (PPKM)

The implementation of Community Activity Restrictions or abbreviated as PPKM is one of the efforts to minimize restrictions on mobility and crowds in the midst of the Covid-19 pandemic. In its application, PPKM is determined in the form of levels, namely between level 1 to level 4. The definition of each level itself is as follows [12]:

a. Level 1: The situation of transmission does not occur, but restrictions are made for prevention efforts or there is transmission but can be controlled through effective actions around cases or clusters of cases.
b. Level 2: A situation of the low incidence of transmission in the community.
c. Level 3: A community transmission situation with limited response capacity and risk of inadequate health services.
d. Level 4: Uncontrolled transmission situation and inadequate response capacity.

While the determination of the PPKM level is based on several criteria, namely as follows:

1. Confirmed Cases: New confirmed cases per 100,000 residents per week.
2. Hospital Inpatient: The number of new hospitalizations for Covid-19 per 100,000 population per week.
3. The number of deaths from Covid-19 per 100,000 population per week.

The implementation of the PPKM level is adjusted to the situation assessment in each district or city. In addition to the criteria above, an assessment is also carried out by looking at indicators of daily confirmed cases, the level of Bed Occupancy Ratio (BOR) or the level of occupancy of beds in the hospital, and vaccination achievement [12].

2.2 Markov Chain

The research methodology that we apply uses the technique of Markov chain theory. Markov chain is a method that studies the properties of a variable in the present based on its properties in the past in an effort to estimate the properties of these variables in the future [9]. The Markov chain can be described as a discrete-time stochastic process that has a finite $(1, \ldots, s)$ number of states and at one time the Markov chain is in one of these states [10]. This situation can be written in equation (1).

$$P(X_{t+1} = i_{t+1} | X_t = i_t, X_{t-1} = i_{t-1}, \ldots \ldots \ldots, X_0 = i_0) \quad (1)$$

With explanation as follows:

X_t = Discrete time stochastic process variable at time t

i_t = State of discrete time stochastic process at time t

Equation (1) explains that the probability distribution of the state in $t + 1$ depends on time t (the previous state) and

does not depend on the Markov chain to reach the state at time t. This can be written as in equation (2).

$$P(X_{t+1} = i_{t+1}|X_t = i_t = p_{ij}) \qquad (2)$$

p_{ij} is the probability that the system is in state i on time t and will be in state j on time $t + 1$. If in a period the system changes from state i to state j, then it can be said that there is a transition from state i to state j. p_{ij}'s can be said to be a possible transition of a Markov chain for one period or one step. whole state i and j and all times t are assumed to be independent. The possible transition matrix P can be written as in equation (3).

$$\boldsymbol{P} = \begin{bmatrix} p_{11} & p_{12} & \cdots & \cdots & p_{1s} \\ p_{21} & p_{22} & \cdots & \cdots & p_{2s} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ p_{s1} & p_{s2} & \cdots & \cdots & p_{ss} \end{bmatrix} \qquad (3)$$

If a system at time t is in state i, then the system is currently $t + 1$ in another state. It means that:

$$\sum_{j=1}^{j=s} P(X_{t+1} = j|P(X_t = i)) = \sum_{j=1}^{j=s} p_{ij} = 1 \qquad (4)$$

A Markov chain can be analyzed if the Markov chain has ergodic states (recurrent, aperiodic, and communicative). In this study it is defined that:

1. The variable X_t is the PPKM level in East Java Province which was observed at time t (the date of observation of the PPKM level classification).
2. The variable i is the state or level of PPKM in East Java Province at the time of t. For example: the state on July 26 is 0 which means at PPKM level a (a depends on the classification of the researcher's state)

In this study, the probability of a state in the long term will be derived. This state is called steady-state in which the Markov chain will settle down and is independent of the initial i state with the probability that π_j the Markov chain will be in state j. This situation can be written as in equation (5).

$$\lim_{t \to \infty} P_{ij}(t) = \pi_j \qquad (5)$$

The vector is called the $\pi = [\pi_1, \pi_2, \dots \dots, \pi_s]$ steady state distribution for the Markov chain. The properties for t large values and for all i can be written as in equation (6) below:

$$P_{ij}(t + 1) \approx P_{ij}(t) \approx \pi_j \; ; \; \pi_j = \sum_{k=1}^{k=s} P_{ik}(t)P_{kj} \qquad (6)$$

For t large ones, equation (7):

$$\pi_j = \sum_{k=1}^{k=s} \pi_k P_{kj} \qquad (7)$$

In matrix form it is written by equation (8) following:

$$\pi = \pi P \qquad (8)$$

The system of equations (8) has an infinite number of solutions because the rank of the matrix P is always $\leq s - 1$. Therefore, to obtain a unique value for the possibility at steady state, it will be obtained based on equations (4) and (8) and the following equation (9) is added:

$$\pi_1 + \pi_2 + \pi_3 + \cdots + \pi_s = 1 \qquad (9)$$

3. METHODOLOGY

3.1 Data

In this study, an analysis of shifts in the level of PPKM in East Java Province will be carried out. The data used in this study is data on the shift of PPKM levels every $1 - 2$ weeks from 38 cities or districts in East Java in the period July 26 – November 29, 2021, sourced from the Instruction of the Minister of Home Affairs.

3.2 Analysis Procedure

In this study, the steps taken for data analysis are as follows:

1. Analyze the distribution of PPKM level mode in East Java Province.
2. Analyze shifts in the level of PPKM in East Java Province with the Markov chain.

   a. Defines the state that is used.
   b. Calculate the frequency of transitions from one state to another or the state itself.
   c. Transformation of the obtained transition frequency into the transition probability matrix.
   d. Determine the steady state probability based on the equation obtained from the transition probability matrix.

3. Draw conclusions based on the results of Markov chain analysis.

4. RESULT AND DISCUSSION

4.1 Distribution of PPKM Level Mode in East Java Province

PPKM levels in 38 cities or districts in East Java Province have different modes. This study uses the PPKM level mode from each city or district with the aim of seeing the trend of the spread of COVID-19 through the PPKM level status in that city or district. The distribution of PPKM level mode in East Java Province is presented in Table 1.

Table 1: Mode of PPKM Level in East Java Province

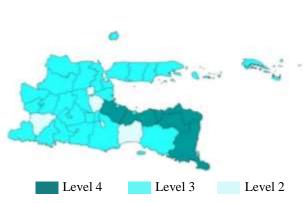| PPKM Level Mode	Number of Cities or District
PPKM Level 2	4
PPKM Level 3	29
PPKM Level 4	4

Fig. 1. *Geographical Distribution of PPKM Level Mode in East Java Province*

Table 1 and Fig. 1 show that most cities or districts in East Java Province are at PPKM level 3 in the period July 26 – November 29, 2021. This provides information that most of the spread of COVID-19 in East Java Province is at the incident level. high with a positive case rate of between 50 to 150 people per hundred thousand inhabitants within a week.

4.2 Changes in PPKM Level in East Java Province

Markov chain is a method that studies the properties of a variable in the present based on its properties in the past in an effort to estimate the properties of these variables in the future. The first step to analyze PPKM level data using a Markov chain is to define the state to be used, the definition of the state used is presented in Table 2.

Table 2: Definition of State

State	Definition of State
State 0	PPKM Level 1
State 1	PPKM Level 2
State 2	PPKM Level 3
State 3	PPKM Level 4

The next step is to calculate the frequency of the transition from one state to another or the state itself. The transition frequency is obtained from the shift of the PPKM level of each City/Regency from the previous period to the next period in accordance with the Instruction of the Minister of Home Affairs. The frequency of the PPKM level transitions from each state is presented in Table 3.

Table 3: Transition Frequency

	State 0	State 1	State 2	State 3
State 0	10	1	0	0
State 1	6	57	9	0
State 2	3	27	208	10
State 3	0	0	41	84

Then Table 3 will be transformed into a transition probability matrix. The transition probability matrix is the probability of moving from one state to another or the state itself. Based on equation (10), the transition probability matrix is obtained as follows:

$$P = \begin{bmatrix} 0{,}909091 & 0{,}090909 & 0{,}000000 & 0{,}000000 \\ 0{,}083333 & 0{,}791667 & 0{,}125000 & 0{,}000000 \\ 0{,}012097 & 0{,}108871 & 0{,}838710 & 0{,}040323 \\ 0{,}000000 & 0{,}000000 & 0{,}328000 & 0{,}672000 \end{bmatrix} \quad (10)$$

Based on equations (4), (8), and (9), equations (11) – (15) can be formed to obtain the probability of a certain state occurring at a steady state. Determining the probability for steady state (π_j) to see the probability of the occurrence of PPKM levels $1 – 4$ in the long term is the aim of this study. Equations (11) – (15) are as follows:

$$\pi_0 = 0{,}909091\pi_0 + 0{,}083333\pi_1 + 0{,}012097\pi_2 \quad (11)$$

$$\pi_1 = 0{,}090909\pi_0 + 0{,}791667\pi_1 + 0{,}108871\pi_2 \quad (12)$$

$$\pi_2 = 0{,}125\pi_1 + 0{,}83871\pi_2 + 0{,}328\pi_3 \quad (13)$$

$$\pi_3 = 0{,}040323\pi_2 + 0{,}672\pi_3 \quad (14)$$

$$\pi_0 + \pi_1 + \pi_2 + \pi_3 = 1 \quad (15)$$

where:

π_0 = Long-term probability of PPKM Level 1

π_1 = Long-term probability of PPKM Level 2

π_2 = Long-term probability of PPKM Level 3

π_3 = Long-term probability of PPKM Level 4

Equations (11) – (15) are solved using the substitution method and produce the solutions presented in Table 4.

Table 4: Steady State Probability

State	Definition of State	Probability
State 0 (π_0)	PPKM Level 1	0.32791
State 1 (π_0)	PPKM Level 2	0.31109
State 2 (π_0)	PPKM Level 3	0.32148

State	Definition of State	Probability
State 0 (π_0)	PPKM Level 1	0.32791
State 3 (π_0)	PPKM Level 4	0.03952

Based on the results of the modeling that has been done, the probability of the PPKM level in the long-term having the potential or having the greatest probability is PPKM level 1 which is 0.32791 and followed by PPKM level 3 is 0.32148 and PPKM level 2 is 0.31109. While the smallest probability of the PPKM level in the long term is PPKM level 4 of 0.03952. This is also in line with the trend of the PPKM level which began to decline in the period 14 September – 20 September 2021 where all districts and cities in East Java Province were no longer at PPKM level 4. The results of this study are relevant for situations where the number of additional cases is at the low to moderate incidence, that is when the addition of positive cases is less than 50 people per 100,000 population per week. The latest data are required if you want to update the long-term probability for the latest PPKM level.

5. CONCLUSION

The Markov chain method can be used for modeling that can predict changes that will occur in the future. In this study, the Markov chain method can be used to analyze changes in the level of PPKM in East Java Province. By using the Markov chain method, the results of this study, especially the PPKM level in East Java Province for the period July 26 – November 29, 2021, shows that most of the spread of COVID-19 in the City/Regency of East Java Province is at a high incidence rate. In addition, based on the modeling results, the probability is obtained in a stable state or steady state. The long-term probability for PPKM to be at level 1 is 0.32791, PPKM is at level 2 is 0.31109, PPKM is at level 3 is 0.32148, and PPKM is at level 4 is 0.03952. So, it can be concluded that the most potential situation is the occurrence of PPKM level 1. The results of this prediction can change depending on the social behavior of the people of East Java. Prediction results can occur if the community continues to implement regular health protocols. On the other hand, the prediction results may not occur if the behavior pattern of the community in implementing health protocols decreases. Thus, the public is advised to always comply with health protocols so as to reduce the spread of COVID-19 which has an impact on reducing PPKM levels.

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