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Leslie Matrix Method for Predicting the Number of Births in Banten Province, Indonesia

Choirul Basir[1,*], Siti Nurasiah[1], Andi Nur Rahman[1], Tabah Heri Setiawan[1]

[1] Department of Mathematics, Faculty of Mathematics and Natural Sciences, Universitas Pamulang, South Tangerang, 15310, Banten, Indonesia

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ABSTRACT

The Leslie Matrix is a model commonly used to predict the growth rate of the female population. Fertility rates and female survival are internal factors in the Leslie matrix that can influence the size of a population. The aim of this research is to apply the Leslie matrix model to predict birth rates during the pandemic in Banten Province. The research method used is determining the research subject, then analysis the data that has been processed using the Python programming language, and finally drawing conclusions. This research data was obtained from the Central Statistics Agency (BPS) of Banten Province, where the number of female residents was from 2015-2020. The result of this research is a Leslie matrix model for the female population in Banten Province which is divided into ten age intervals which are constructed using fertility rates and life expectancy levels. The conclusion of this research is that the eigenvalue is 0.7632, therefore births during the pandemic in Banten Province tend to decrease by 23.6744% or it could be said that the number of births in Banten Province tends to have a negative value.

1. Introduction

Population growth in a region is a dynamic combination of factors that influence growth or reduce the population. According to the Central Statistics Agency (BPS), population is people who have been domiciled in the geographical area of the Republic of Indonesia for a period of 6 months or more or those who are domiciled less than 6 months but aims to stay. The rate of population growth in an area can be caused by several factors, namely births, deaths and women's survival. These three factors can predict population growth whether the population will increase, decrease or be stable in the coming year. Through a census conducted by the Central Statistics Agency (BPS) which is held every 10 years, the average population growth rate in 2010-2020 reached 1.25 percent.

* *Corresponding author.*
E-mail address: dosen02278@unpam.ac.id

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This figure tends to decrease compared to the 2000-2010 period which reached an average of 1.49 percent, with the following details

Fig. 1. Number and Growth Rate of Indonesia's Population, 1961 – 2020

Based on figure 1, it can be seen that there has been a slowdown in the population growth rate of 0.24 percent. Even though the population growth rate continues to decline, Indonesia's population continues to increase. This is based on the results of the 2020 population census, Indonesia's population reached 270.20 million people, consisting of 136.66 million or 50.58 percent of the male population and 133.54 million or 49.42 percent of the female population (Central Statistics Agency 2019). Based on the results of the population census (SP) and the Central Statistics Agency (BPS) in 2020, West Java Province is the province with the first largest population in Indonesia, reaching 48.27 million people, around 17 percent of Indonesia's total population. Banten Province is the province with the fifth largest population in Indonesia with a population reaching 11.90 million people consisting of 6,070,271 male residents and 5,834,291 female residents.

Banten Province is one of the provinces on the island of Java, Indonesia. With the government center located in Serang City with an area of 9,663 km2. The high population in Banten Province is caused by the high birth rate. One of the factors in this high birth rate is the increasing number of young marriages during the Covid-19 pandemic. The Covid-19 pandemic that hit Indonesia in early 2020 had an impact on government policy in implementing social distancing to reduce the spread of the virus, resulting in limited population activities. The implementation of work at home and distance (online) learning causes people to spend a lot of time at home so that the intensity of meetings between couples at home will increase. As a result, the reproductive process occurs more frequently. Moreover, access to contraception may be limited due to the surge in pregnancies occurring or the lack of family planning (KB) acceptors visiting health services. Thus, it is natural that the birth rate will eventually increase amidst the current pandemic.

2. Methodology

A matrix is an arrangement of elements in the form of numbers arranged in a rectangular shape and consisting of several rows and several columns and closed with two square brackets (Andari, A 2017).

$$A_{mxn} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ . & . & \dots & . \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix}$$

The matrix $A_{m\times n}$ above is a general form of matrix consisting of m rows and n columns. The entries $a_{11}, a_{22}, \dots, a_{mn}$ are said to lie on the main diagonal of A. The rows in matrix A are m horizontal rows with scalars $(a_{11}, a_{12}, \dots, a_{1n}), (a_{21}, a_{22}, \dots, a_{2n}), \dots, (a_{m1}, a_{m2}, \dots, a_{mn})$. And the columns of matrix A are n vertical rows with scalars:

$$\begin{bmatrix} a_{11} \\ a_{21} \\ \dots \\ a_{m1} \end{bmatrix}, \begin{bmatrix} a_{21} \\ a_{22} \\ \dots \\ a_{m2} \end{bmatrix}, \dots, \begin{bmatrix} a_{1n} \\ a_{2n} \\ \dots \\ a_{mn} \end{bmatrix}$$

The location of an element a_{ij} in the matrix shows that i is a row while j is a column. For example, an entry a_{12} shows an element that is in the 1st row with the 2nd column. A matrix with m rows and n columns is called an m x n matrix with the notation symbol A_{mn}.
The following are the steps in this research:

1. Study of literature
   Study various sources of information from books and journals related to the application of the Leslie matrix model to predict the number of births and population growth rate.
2. Examining the Leslie matrix model
   Several things that need to be studied regarding the application of the Leslie matrix model are determining the Leslie matrix model, the parameters in the Leslie matrix model and the eigenvalues function to determine the growth rate of a population and the eigenvectors to determine whether the age distribution of a population is stable or not.
3. Data collection
   Collecting data on the number of female residents based on age class, the number of child births based on the mother's age at birth, and the number of women's survival in Banten Province, Indonesia.
4. Looking for fertility rates and women's survival rates.
   Look for the value of the female fertility rate (a_i) where the average number of girls born to each woman when the mother is in the i-th age class. As well as looking for the survival rate (b_i) value where the ratio of women in the i-th age class who are expected to reach the $(i+1)$th age class

Determine the eigenvalues of the Leslie matrix model which is used to project the number and growth rate of a population. The eigenvalues are looked for positive eigenvalues λ_1. The following are the conditions for changes in population size related to the value of positive eigenvalues λ_1:

a. The number of a population can increase if $\lambda_1 > 1$.
b. The number of a population can decrease if $\lambda_1 < 1$.
c. The number of a population tends to be stable if $\lambda_1 = 1$.

3. Results

3.1 Element of Leslie Matrix

The Leslie Matrix is a model that predicts female population growth, where women in the population are grouped into age classes within the same time period. A population is represented by a vector with elements for each age class where each age class defines the number of individuals in that age class. In the Leslie matrix method, it is assumed that the growth rate of the female population is influenced by female births and deaths and there is assumed to be no in-migration or out-migration in population studied.

The analysis used in designing this thesis is to analysis whether the requirements for the Leslie matrix model have been fulfilled so that the Leslie matrix model can be used for female population problems. After that, look for the value of the fertility rate (a_i), namely the average number of daughters born to each woman when the mother is in the i-th age class and look for the survival rate (b_i), namely the ratio of women in the i-th age class who are expected to survive and reach the ($i + 1$) age class. After the fertility rate (a_i) and survival rate values (b_i) have been obtained, the next step is to predict the number of female populations using the initial female population. To find out the population growth rate, the growth of the female population is looked for positive eigenvalues and the Leslie matrix model uses the Python programming language, so that vectors related to positive eigenvalues can be identified.

The characteristics of the Leslie matrix model are as follows:

1. The Leslie Matrix is a square matrix with a population vector that has elements with the same number of rows and columns.
2. The Leslie matrix has a single positive eigenvalue λ_1. This eigenvalue has a multiplicity of 1 and is an eigenvector X_1 with all its elements having positive values.
3. If a Leslie matrix L with λ_1 which is a single positive eigenvalue and λ_k is any real number eigenvalue of L then $|\lambda_k| \leq \lambda_1$.
4. A Leslie matrix L is said to be dominant if two consecutive entries a_i and a_{i+1} are contained in the first row.

3.2 Predicting Population Size with the Leslie Matrix Model

The Leslie matrix model is a population growth rate model commonly used by demographers and was developed in 1945 by P.H. Leslie. The general form of the Leslie matrix model is

$$L=\begin{bmatrix} a_1 & a_2 & a_3 & \dots & a_{n-1} & a_n \\ b_1 & 0 & 0 & \dots & 0 & 0 \\ 0 & b_1 & 0 & \dots & 0 & 0 \\ \vdots & \vdots & \vdots & & \vdots & \vdots \\ 0 & 0 & 0 & \dots & b_{n-1} & 0 \end{bmatrix}$$

Information:
a_i : the average number of daughters born to a woman during her age class.
b_i : the number of women in the 1st age class who can survive to the 2nd age class.

3.3 Female Population Data

Data used sources on the female population in Banten Province for 2015-2020 in this research. This data includes the female population in 2015 and 2020 based on age class, births of children based on the mother's age class at birth. This data is grouped into age classes over a period of 5 years, in total there are 10 age classes.

Table 1
Data on Female Population in Banten Province, Indonesia 2015-2020

Age Interval (years)	Number of Women in 2015	Number of Girls Born	Number of Women in 2020
10-14	524,890	0	485,428
15-19	505,483	11,797	489,235
20-24	543,058	46,998	510.711
25-29	539,463	47,701	509,196
30-34	528,376	41,964	508,073
35-39	510,381	25,747	480,135
40-44	410,191	7,646	446,577
45-49	358,023	1,349	389,864
50-54	241,062	0	319,612
55+	530,400	0	252,441
TOTAL	4,691,327	183,202	4,391,272

From the data seen in table 1, data analysis was carried out by calculating fertility rates and life expectancy rates. The Leslie matrix model is used to predict the number of female populations in the next 5 years.

3.4 Leslie Matrix Model

In the Leslie matrix model the entries are formed from fertility rates (a_i) and survival rates (b_i). It is known that a_i the average population of girls born to each woman in the i-th age class, with the $a_i \geq 0$ following $i = 1, 2, 3, \ldots, n,$ conditions:

$$a_i = \frac{A_i}{x_i^{(0)}} \quad (i = 1, 2, 3, ..., n)$$

Information:

a_i : female fertility rate.

A_i : the number of girls born.

x_i : number of women born according to age class in year i.

From table 1, the fertility rate can be obtained using the equation above. Obtained value,

$$a_1 = \frac{A_1}{x_1^{(0)}} = \frac{0}{524.890} = 0$$

$$a_2 = \frac{A_2}{x_2^{(0)}} = \frac{11.797}{505.483} = 0,0233$$

$$a_3 = \frac{A_3}{x_3^{(0)}} = \frac{46.998}{543.058} = 0,0865$$

$$a_4 = \frac{A_4}{x_4^{(0)}} = \frac{47.701}{539.463} = 0,0884$$

$$a_5 = \frac{A_5}{x_5^{(0)}} = \frac{41.964}{528.376} = 0,0794$$

$$a_6 = \frac{A_6}{x_6^{(0)}} = \frac{25.747}{510.381} = 0,0504$$

$$a_7 = \frac{A_7}{x_7^{(0)}} = \frac{7.646}{410.191} = 0,0186$$

$$a_8 = \frac{A_8}{x_8^{(0)}} = \frac{1.349}{358.023} = 0,0038$$

$$a_9 = \frac{A_9}{x_9^{(0)}} = \frac{0}{241.062} = 0$$

$$a_{10} = \frac{A_{10}}{x_{10}^{(0)}} = \frac{0}{530.400} = 0$$

It is known that the survival rate of women is where the probability of women in the 1st age class being able to survive reaches the 1st age class $(i+1)$ with the provisions $0 < b_i < 1$ for $(i = 1, 2, 3, ..., n-1)$, then:

$$b_i = \frac{B_i}{x_i^{(0)}} \quad (i = 1, 2, 3, ..., n)$$

Information:

b_i : female survival rate.

B_i : number of women born in year i.

x_i : number of women born according to age class in year i.

From table 1, the fertility rate can be obtained using the equation above. Obtained value,

$$b_i = \frac{B_i}{x_i^{(0)}} = \frac{489.428}{524.890} = 0,9321$$

$$b_i = \frac{B_i}{x_i^{(0)}} = \frac{510.711}{505.483} = 1,0103$$

$$b_i = \frac{B_i}{x_i^{(0)}} = \frac{509.196}{543.058} = 0,9376$$

$$b_i = \frac{B_i}{x_i^{(0)}} = \frac{508.073}{539.463} = 0,9418$$

$$b_i = \frac{B_i}{x_i^{(0)}} = \frac{480.135}{528.376} = 0,9087$$

$$b_i = \frac{B_i}{x_i^{(0)}} = \frac{446.577}{510.381} = 0,8750$$

$$b_i = \frac{B_i}{x_i^{(0)}} = \frac{389.864}{410.191} = 0,9504$$

$$b_i = \frac{B_i}{x_i^{(0)}} = \frac{319.612}{358.023} = 0,8927$$

$$b_i = \frac{B_i}{x_i^{(0)}} = \frac{252.441}{241.062} = 1,0472$$

Table 2
Data on fertility rates and women's survival in Banten Province 2015-2020

Age Interval (years)	(a_i)	(b_i)
10-14	0	0,9321
15-19	0,0233	1,0103
20-24	0,0865	0,9376
25-29	0,0884	0,9418
30-34	0,0794	0,9087
35-39	0,0504	0,8750
40-44	0,0186	0,9504
45-49	0,0038	0,8927
50-54	0	1,0472
55+	0	0

3.5 Eigenvalues

So, by using the approximate equation for the limiting age distribution, namely $x^{(k)} \approx \lambda_1 x^{(k-1)}$, so that $x^{(k)} \approx 0{,}7632\, x^{(k-1)}$. So from these eigenvalues we get $\lambda_1 < 1$, so that every year the female population in Banten Province tends to decrease or it could be said that the growth rate of the female population in Banten Province tends to be negative, namely 23.6744%.

4. Conclusions

Based on the results of data analysis using the Leslie matrix model on the female population in Banten Province, conclusions can be drawn, namely: The following fertility rate (a_i) and survival rate (b_i) values were obtained:

$$(a_i) = \begin{pmatrix} a_i^{(1)} = 0 \\ a_i^{(2)} = 0{,}0233 \\ a_i^{(3)} = 0{,}0884 \\ a_i^{(4)} = 0{,}0794 \\ a_i^{(5)} = 0{,}0504 \\ a_i^{(6)} = 0{,}0186 \\ a_i^{(7)} = 0{,}0038 \\ a_i^{(8)} = 0 \\ a_i^{(9)} = 0 \end{pmatrix} \text{ and } (b_i) = \begin{pmatrix} b_i^{(1)} = 0{,}9319 \\ b_i^{(2)} = 1{,}0103 \\ b_i^{(3)} = 0{,}9376 \\ b_i^{(4)} = 0{,}9418 \\ b_i^{(5)} = 0{,}9087 \\ b_i^{(6)} = 0{,}8750 \\ b_i^{(7)} = 0{,}8927 \\ b_i^{(8)} = 1{,}0472 \\ b_i^{(9)} = 0 \end{pmatrix}.$$

The eigenvalue obtained from the Leslie matrix with this data is 0.7632. And obtained a limiting age distribution approach, namely $x^{(k)} \approx 0{,}7632\, x^{(k-1)}$ with a large k value and it is known that the prediction of births in the female population in Banten Province uses the Leslie matrix model, namely: $x^{(1)} = 4.069.337$, $x^{(2)} = 3.685.522$, $x^{(3)} = 3.266.325$, $x^{(4)} = 2.810.835$, and $x^{(5)} = 2.375.681$.

So, it can be seen that every year the number of births after the pandemic has decreased, namely in 2021, 2022, 2023, 2024 and 2025. This means that the population will decrease in the following year or it can be said that the growth rate of the female population in Banten Province tends to be negative. namely 23.6744%.

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References

[1] Alvian, Muhammad Ilham, Iyep Saefulrahman, and Desi Yunita. "Efektivitas Program Kota Layak Anak Di Jakarta Barat Selama Pandemi Covid-19 Tahun 2021 (Studi Pada Suku Dinas Pemberdayaan, Perlindungan Anak Dan Pengendalian Penduduk Jakarta Barat)." *Jurnal Administrasi Pemerintahan (Janitra)* 4, no. 1 (2024): 163-171.

[2] Disdukcapil, "Profil Perkembangan Kependudukan Provinsi DKI Jakarta Tahun 2022," 2023.

[3] Hidayati, Nazly, Andika Putra, Metra Dewita, and Novira Esa Framujiastri. "Dampak dinamika kependudukan terhadap lingkungan." *Jurnal Kependudukan dan Pembangunan Lingkungan* 1, no. 2 (2020): 80-89.

[4] C. Basir and Aden, "PRAKTIKUM PEMODELAN MATEMATIKA," pp. 38–47, 2022.

[5] R. W. Paramita, N. Rizal, and R. Sulistian, *Metode penelitian kuantitatif*, Ketiga. Widya Gama Press, 2021.

[6] Badan Pusat Statistik JakBar, *Kota Jakarta Barat Dalam Angka 2019*. Jakarta Barat: BPS Kota Administrasi Jakarta Barat, 2019.
[7] BPS Jakarta Barat, *Kota Jakarta Barat Dalam Angka 2024*, vol. 51. Kota Administrasi Jakarta Barat: BPS Kota Administrasi Jakarta Barat, 2024.
[8] Badan Pusat Statistik Jakarta Barat, *Indikator Kesejahteraan Rakyat Kota Jakarta Barat 2023*. Kota Administrasi Jakarta Barat, 2023.
[9] D. Anggreini and R. C. Hastari, "Application of the Leslie Matrix on Birth Rate and Life Expectancy of Women in East Java Province," vol. 12, no. 2, pp. 109–122, 2017.
[10] D. Anggreini, *Aplikasi matriks dalam menentukan pertumbuhan populasi*, 1st ed., no. February. D.I. Yogyakarta: Lintas Nalar,CV, 2017.
[11] Ruminta, *Matriks Persamaan Linier dan Pemrograman Linier*. Bandung: Rekayasa Sains, 2014.
[12] Riska, Herliana, and Nur Khasanah. "Faktor yang memengaruhi fenomena menunda pernikahan pada generasi Z." *Indonesian Health Issue* 2, no. 1 (2023): 48-53. https://doi.org/10.47134/inhis.v2i1.44
[13] M. Sugara and Arnellis, "Matriks Leslie dan Aplikasinya pada Pemodelan Jumlah Populasi Perempuan di Sumatera Barat," vol. 6, no. 4, pp. 16–22, 2021.
[14] Maryati, Ati, Sudrajat Supian, and Subiyanto Subiyanto. "Application of the Leslie Matrix to Predict the Number and Growth Rate of Women in West Java 2021." *International Journal of Quantitative Research and Modeling* 2, no. 1 (2021): 11-23. https://doi.org/10.46336/ijqrm.v2i1.78
[15] Pratiwi, Yuliyanti Dian, Nurul Hidayati, Melli Mariska, Sarlita Indah Sagita, and Axioma Elmonura Gusaynsan. "Aplikasi Matriks Leslie untuk Memproyeksi Jumlah Penduduk Perempuan dan Laju Pertumbuhan Penduduk di Kabupaten Banyumas Tahun 2027." *Proceedings Series on Physical & Formal Sciences* 6 (2023): 67-72. https://doi.org/10.30595/pspfs.v6i.855
[16] Marzuki, C. C., Yuslenita Muda, and Nurul Hasanah. "Aplikasi matriks Leslie untuk memprediksi jumlah dan laju pertumbuhan perempuan di Provinsi Riau pada tahun 2017." *Jurnal Sains Matematika dan Statistika* 2, no. 1 (2016): 37-48.
[17] T. Sutojo, Bowo, Erna, S. Astuti, Y. Rahayu, and E. Mulyanto, *Teori dan Aplikasi Aljabar Linier & Matriks*, 1st ed. Yogyakarta: C.V ANDI OFFSET, 2010.
[18] Leslie, Patrick H. "Some further notes on the use of matrices in population mathematics." *Biometrika* 35, no. 3/4 (1948): 213-245. https://doi.org/10.1093/biomet/35.3-4.213
[19] Badan Pusat Statistik Indonesia, *Perempuan dan Laki-Laki 2023 di Indonesia*, vol. 14. Indonesia, 2023.
[20] M. Leslie, W. Sanusi, and N. Ridiawati, "Matriks Leslie dan Aplikasinya dalam Memprediksi Jumlah dan Laju pertumbuhan Penduduk di Kota Makassar," no. January, 2020. https://doi.org/10.35580/jmathcos.v1i2.9189
[21] C. Basir and Aden, *Praktikum Pemodelan Matematika (dengan Python)*. Tangerang Selatan: Unpam Press, 2022.