SEMARAK ILMU PUBLISHING

Semarak International Journal of Current Research in Language and Human Studies

Journal homepage:
https://semarakilmu.my/index.php/sijcrlhs/index
ISSN: 3083-9572

Population Projection and Growth Rate using Leslie Matrix Model for Female Resource Mapping

Nofi Triana Sari[1], Isnurani[1,*], Choirul Basir[1]

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

ARTICLE INFO

Article history:
Received 9 July 2025
Received in revised form 18 August 2025
Accepted 12 September 2025
Available online 22 September 2025

Keywords:
Eigenvalue; growth rate; leslie matrix; women's resources

ABSTRACT

The Leslie matrix is a mathematical model used to predict the number and growth rate of the female population. Fertility and survival rates of women are internal factors in the Leslie matrix that can affect the size of a population. The purpose of this study is to implement the Leslie matrix model in projecting the number and growth rate of the female population in each age group in West Jakarta City. The research method used is quantitative descriptive research, determining the object of research, analyzing the data that has been processed using the Python programming language, and drawing conclusions. The research data used in this study is secondary data with the number of female residents and the number of children born based on the age of the mother in 2018-2023. The result of this research is a Leslie matrix model for the female population in West Jakarta City with 16 age intervals constructed using the value of fertility and survival rates. The conclusion of this research is that the eigenvalue of 0.8613 is obtained and the population decreases in the following year and it can be said that the female population growth rate in West Jakarta City tends to be negative, which is 13.8703%.

1. Introduction

The goal of the development plan contained in the 2005-2025 RPJM is to improve the quality of human resources, including the role of women in development [1]. The DKI Jakarta Provincial Government continues to improve the welfare of the community through various sustainable development programs [2]. Population density can affect the quality of life of the population. However, in areas with high population density, efforts to improve the quality of the population will be more difficult. This can lead to other problems such as welfare, security, land availability, clean water and food needs. The high growth rate also makes it difficult to provide the needs of the population such as food, clothing, shelter, educational facilities, and employment [3].

* *Corresponding author.*
E-mail address: dosen01193@unpam.ac.id

https://doi.org/10.37934/sijcrlhs.3.1.5161

The following will present population growth rate data from the Population and Civil Registration Office of DKI Jakarta Province in 2022 to see the population growth rate in West Jakarta City [2].

Table 1
Population growth rate of DKI Jakarta province

No.	District/City Region Administration	Year 2020-2021	Year 2021-2022
1	Thousand Islands	1.22	1.46
2	Central Jakarta	-1.41	-2.68
3	North Jakarta	1.16	0.49
4	West Jakarta	0.67	0.85
5	South Jakarta	0.58	0.95
6	East Jakarta	0.95	1.05
DKI Jakarta Province		0.60	0.52

Source: Population and Civil Registration Office of DKI Jakarta Province in 2022, processed

West Jakarta Administrative City is one of the administrative areas under the DKI Jakarta Provincial Government. It can be seen from table 1 above that the population growth rate in West Jakarta has increased in 2022 with a high population density compared to other cities. The number of residents continues to increase from year to year. If population growth is uncontrolled, the implication of this is the emergence of various socio-economic problems such as increased crime, increased slum growth, and so on. Given the central role of women in population growth, it is important that women often have a significant impact on family and community dynamics including decisions about the number of children.

The female population can be known by modeling its population growth using a mathematical model, namely by using the Leslie matrix. The Leslie matrix is a matrix that can be used to predict the growth rate of a population depending on the factors used in determining the growth of a population [4].

2. Methodology

This research uses quantitative descriptive research. The population that became the object of research was the female population in West Jakarta in 2018 and 2023. Data collection uses secondary data from the West Jakarta Central Bureau of Statistics and the DKI Jakarta Population and Civil Registration Office. Data analysis techniques used to predict the population and population growth rate of women in West Jakarta based on birth rates and life expectancy using eigenvalues and eigenvectors and to determine the limiting age distribution using the Leslie Matrix model [5].

3. Results

3.1 Female Population Data

The first step to calculate the number and rate of population growth is to group the data on the number of female residents by age in 2018 and 2023 as shown in Table 2.

Table 2
Female population data in West Jakarta City in 2018 and 2023

Age Class	Age Interval	Number of Women in 2018	Number of daughters born	Number of Women in 2023
1	0-4	93,652	0	86,750
2	5-9	102,301	0	104,470
3	10-14	96,140	14	105,932
4	15-19	92,747	426	99,298
5	20-24	89,656	4,076	98,115
6	25-29	100,078	9,522	98,234
7	30-34	111,950	8,167	103,622
8	35-39	123,321	4,627	109,083
9	40-44	103,692	1,265	117,626
10	45-49	87,947	77	98,808
11	50-54	70,648	105	82,640
12	55-59	55,539	0	64,593
13	60-64	42,068	0	49,144
14	65-69	26,649	0	36,214
15	70-74	17,969	0	25,469
16	75+	13,986	0	19,403
Total		1,228,343	28.279	1,299,401

Source: Central Bureau of Statistics [6-8]

3.2 Calculating the Class Interval

Determining the age class interval of the female population in West Jakarta Administrative City in 2018-2023 using the Leslie matrix model age class determination table. The age class interval used in this study is the age class interval determined by the Population and Civil Registration Office of DKI Jakarta Province. Based on Table 3, assuming the value of M is 75 years and n is 15 classes, the age range in each age class can be determined as in the following table

Table 3
Determination of age interval

Age class (i)	Age Interval	Age class (i)	Age Interval
1	$\left[0,\frac{M}{n}\right)=\left[0,\frac{75}{15}\right)=[0,5)$	9	$\left[\frac{8M}{n},\frac{9M}{n}\right)=\left[\frac{600}{15},\frac{675}{15}\right)=[40,45)$
2	$\left[\frac{M}{n},\frac{2M}{n}\right)=\left[\frac{75}{15},\frac{150}{15}\right)=[5,10)$	10	$\left[\frac{9M}{n},\frac{10M}{n}\right)=\left[\frac{675}{15},\frac{750}{15}\right)=[45,50)$
3	$\left[\frac{2M}{n},\frac{3M}{n}\right)=\left[\frac{150}{15},\frac{225}{15}\right)=[10,15)$	11	$\left[\frac{10M}{n},\frac{11M}{n}\right)=\left[\frac{750}{15},\frac{825}{15}\right)=[50,55)$
4	$\left[\frac{3M}{n},\frac{4M}{n}\right)=\left[\frac{225}{15},\frac{300}{15}\right)=[15,20)$	12	$\left[\frac{11M}{n},\frac{12M}{n}\right)=\left[\frac{825}{15},\frac{900}{15}\right)=[55,60)$
5	$\left[\frac{4M}{n},\frac{5M}{n}\right)=\left[\frac{300}{15},\frac{375}{15}\right)=[20,25)$	13	$\left[\frac{12M}{n},\frac{13M}{n}\right)=\left[\frac{900}{15},\frac{975}{15}\right)=[60,65)$
6	$\left[\frac{5M}{n},\frac{6M}{n}\right)=\left[\frac{375}{15},\frac{450}{15}\right)=[25,30)$	14	$\left[\frac{13M}{n},\frac{14M}{n}\right)=\left[\frac{975}{15},\frac{1.050}{15}\right)=[65,70)$
7	$\left[\frac{6M}{n},\frac{7M}{n}\right)=\left[\frac{450}{15},\frac{525}{15}\right)=[30,35)$	15	$\left[\frac{14M}{n},M\right)=\left[\frac{1.050}{15},75\right)=[70,75)$
8	$\left[\frac{7M}{n},\frac{8M}{n}\right)=\left[\frac{525}{15},\frac{600}{15}\right)=[35,40)$		

Based on Table 3 above, the female population of West Jakarta City in 2018 and 2023 is divided into 16 age classes with the same age interval for each age class of 5 years except for the last age class. The number of age classes will be equal to the number of values a_i , b_i and the size of the Leslie matrix.

3.3 Calculating the Fertility Rate Value

Female fertility rate in Leslie matrix is denoted by a_i. Defined a_i is the average number of daughters born to a woman while the mother is in the-i age class. It is known $a_i > 0$ because if $a_i = 0$ then in that class no births occur. Each age class that has a value of $a_i > 0$ is called a fertility age class [9].

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

Where,
A_i : Number of female births at age group to x_i.
$x_i^{(t_k)}$: Female population in age class to x_i at time t_k.

$$a_1 = \frac{A_1}{x_1^{(0)}} = \frac{0}{93{,}652} = 0$$
$$a_2 = \frac{A_2}{x_2^{(0)}} = \frac{0}{102{,}301} = 0$$
$$a_3 = \frac{A_3}{x_3^{(0)}} = \frac{14}{96{,}140} = 0.0001$$
$$a_4 = \frac{A_4}{x_4^{(0)}} = \frac{426}{92{,}747} = 0.0046$$
$$a_5 = \frac{A_5}{x_5^{(0)}} = \frac{4{,}076}{89{,}656} = 0.0455$$
$$a_6 = \frac{A_6}{x_6^{(0)}} = \frac{9{,}522}{100{,}078} = 0.0951$$
$$a_7 = \frac{A_7}{x_7^{(0)}} = \frac{8{,}167}{111{,}950} = 0.0730$$
$$a_8 = \frac{A_8}{x_8^{(0)}} = \frac{4{,}627}{123{,}321} = 0.037$$
$$a_9 = \frac{A_9}{x_9^{(0)}} = \frac{1{,}265}{103{,}692} = 0.0122$$
$$a_{10} = \frac{A_{10}}{x_{10}^{(0)}} = \frac{77}{87{,}947} = 0.0009$$
$$a_{11} = \frac{A_{11}}{x_{11}^{(0)}} = \frac{105}{70{,}648} = 0.0015$$
$$a_{12} = \frac{A_{12}}{x_{12}^{(0)}} = \frac{0}{55{,}539} = 0$$

$$a_{13} = \frac{A_{13}}{x_{13}^{(0)}} = \frac{0}{42{,}068} = 0$$
$$a_{14} = \frac{A_{14}}{x_{14}^{(0)}} = \frac{0}{26{,}649} = 0$$
$$a_{15} = \frac{A_{15}}{x_{15}^{(0)}} = \frac{0}{17{,}969} = 0$$
$$a_{16} = \frac{A_{16}}{x_{16}^{(0)}} = \frac{0}{13{,}986} = 0$$

3.4 Calculating the Survival Rate Value

Female survival rate in Leslie matrix is denoted by b_i which has the following conditions: $0 < b_i \leq 1$ for $i = 1,2,\ldots,n-1$. Defined b_i is the number of women in the i-th age group who can be expected to survive to the - $(i+1)$ age group.

$$b_i = \frac{x_{i+1}^{(t_{k+1})}}{x_i^{(t_k)}}, (i-1,2,3,\ldots,n) \quad (2)$$

Where,
$x_{i+1}^{(t_{k+1})}$: Female population in age class to $-x_{i+1}$ at time t_{k+1}.
$x_i^{(t_k)}$: Female population in age class to $-x_i$ at time t_k.

$$b_1 = \frac{x_{1+1}^{(1)}}{x_1^{(0)}} = \frac{x_2^{(1)}}{x_1^{(0)}} = \frac{104{,}470}{93{,}652} = 1.1155$$
$$b_2 = \frac{x_{2+1}^{(1)}}{x_2^{(0)}} = \frac{x_3^{(1)}}{x_2^{(0)}} = \frac{105{,}932}{102{,}301} = 1.0355$$
$$b_3 = \frac{x_{3+1}^{(1)}}{x_3^{(0)}} = \frac{x_4^{(1)}}{x_3^{(0)}} = \frac{99{,}298}{96{,}140} = 1.0328$$
$$b_4 = \frac{x_{4+1}^{(1)}}{x_4^{(0)}} = \frac{x_5^{(1)}}{x_4^{(0)}} = \frac{98{,}115}{92{,}747} = 1.0579$$
$$b_5 = \frac{x_{5+1}^{(1)}}{x_5^{(0)}} = \frac{x_6^{(1)}}{x_5^{(0)}} = \frac{98{,}234}{89{,}656} = 1.0957$$
$$b_6 = \frac{x_{6+1}^{(1)}}{x_6^{(0)}} = \frac{x_7^{(1)}}{x_6^{(0)}} = \frac{103{,}622}{100{,}078} = 1.0354$$
$$b_7 = \frac{x_{7+1}^{(1)}}{x_7^{(0)}} = \frac{x_8^{(1)}}{x_7^{(0)}} = \frac{109{,}083}{111{,}950} = 0.9744$$
$$b_8 = \frac{x_{8+1}^{(1)}}{x_8^{(0)}} = \frac{x_9^{(1)}}{x_8^{(0)}} = \frac{117{,}626}{123{,}321} = 0.9538$$
$$b_9 = \frac{x_{9+1}^{(1)}}{x_9^{(0)}} = \frac{x_{10}^{(1)}}{x_9^{(0)}} = \frac{98{,}808}{103{,}692} = 0.9529$$

$$b_{10} = \frac{x_{10+1}^{(1)}}{x_{10}^{(0)}} = \frac{x_{11}^{(1)}}{x_{10}^{(0)}} = \frac{82{,}640}{87{,}947} = 0.9397$$
$$b_{11} = \frac{x_{11+1}^{(1)}}{x_{11}^{(0)}} = \frac{x_{12}^{(1)}}{x_{11}^{(0)}} = \frac{64{,}593}{70{,}648} = 0.9143$$

$$b_{12} = \frac{x_{12+1}^{(1)}}{x_{12}^{(0)}} = \frac{x_{13}^{(1)}}{x_{12}^{(0)}} = \frac{49{,}144}{55{,}539} = 0.8849$$
$$b_{13} = \frac{x_{13+1}^{(1)}}{x_{13}^{(0)}} = \frac{x_{14}^{(1)}}{x_{13}^{(0)}} = \frac{36{,}214}{42{,}068} = 0.8608$$
$$b_{14} = \frac{x_{14+1}^{(1)}}{x_{14}^{(0)}} = \frac{x_{15}^{(1)}}{x_{14}^{(0)}} = \frac{25{,}469}{26{,}649} = 0.9557$$
$$b_{15} = \frac{x_{15+1}^{(1)}}{x_{15}^{(0)}} = \frac{x_{16}^{(1)}}{x_{15}^{(0)}} = \frac{19{,}403}{17{,}969} = 1.0798$$

3.5 Constructing the Leslie matrix

Based on the results of the calculation of the fertility value and the survival value above, a Leslie Matrix Model (L) of 16×16 is constructed, a Leslie Matrix is obtained with its matrix elements consisting of Fertility Level (a_i) in the first row and Survival Level (b_i) on the sub diagonal, and entries other than in the first row and sub diagonal are 0 [8].
Where L is the Leslie Matrix

$$L = \begin{bmatrix} a_1 & a_2 & a_3 & \dots & a_{n-1} & a_n \\ b_1 & 0 & 0 & \dots & 0 & 0 \\ 0 & b_2 & 0 & \dots & 0 & 0 \\ \vdots & \vdots & \vdots & & \vdots & \vdots \\ 0 & 0 & 0 & \dots & b_{n-1} & 0 \end{bmatrix} \quad (3)$$

$$L = \begin{bmatrix} 0 & 0 & 0.0001 & 0.0046 & 0.0455 & 0.0951 & 0.0730 & 0.0375 & 0.0122 & 0.0009 & 0.0015 & 0 & 0 & 0 & 0 & 0 \\ 1.1155 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1.0355 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1.0328 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1.0579 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1.0957 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1.0354 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0.9744 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.9538 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.9529 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.9397 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.9143 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.8849 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.8608 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.9557 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1.0798 & 0 \end{bmatrix}$$

3.6 Projecting the Population Size

To predict the number of women in the coming year, we can use equation (4) as follows. From the equation $x^{(k)} = Lx^{(k-1)}$ it is found that

$$x^{(1)} = Lx^{(0)}$$
$$x^{(2)} = Lx^{(1)} = L^2x^{(0)}$$
$$\vdots$$
$$x^{(k)} = Lx^{(k-1)} = L^kx^{(0)} \quad (4)$$

Where,

$x^{(k)}$: Population vector containing the estimated female population at time k

L : The Leslie matrix is of size $n \times n$.

$x^{(k-1)}$: Population vector containing the population in the age class at time k-1

So, if the starting age distribution is known $x^{(0)}$ and Leslie matrix L, the age distribution of females or females at any future time can be determined. [10].

Based on the table of results of the fertility rate and survival rate above and from the equation above, the female growth model in West Jakarta City for the coming year is obtained with the Leslie matrix as follows:

$$x^{(5)} = Lx^{(4)} =$$

$$\begin{bmatrix} 0 & 0 & 0.0001 & 0.0046 & 0.0455 & 0.0951 & 0.0730 & 0.0375 & 0{,}0122 & 0.0009 & 0.0015 & 0 & 0 & 0 & 0 & 0 \\ 1.1155 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1.0355 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1.0328 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1.0579 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1.0957 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1.0354 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0.9744 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.9538 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.9529 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.9397 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.9143 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.8849 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.8608 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.9557 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1.0798 & 0 \end{bmatrix} \begin{bmatrix} 32{,}055 \\ 33{,}463 \\ 32{,}616 \\ 32{,}899 \\ 109{,}487 \\ 129{,}507 \\ 131{,}309 \\ 116{,}119 \\ 103{,}450 \\ 90{,}079 \\ 86{,}232 \\ 85{,}178 \\ 85{,}207 \\ 64{,}661 \\ 55{,}005 \\ 50{,}776 \end{bmatrix} = \begin{bmatrix} 32{,}861 \\ 35{,}758 \\ 34{,}651 \\ 33{,}687 \\ 34{,}803 \\ 119{,}963 \\ 134{,}093 \\ 127{,}946 \\ 110{,}757 \\ 98{,}577 \\ 84{,}643 \\ 78{,}841 \\ 75{,}370 \\ 73{,}350 \\ 61{,}798 \\ 59{,}395 \end{bmatrix}$$

$$x^{(5)} = 32{,}861 + 35{,}758 + 34{,}651 + 33{,}687 + 34{,}803 + 119{,}963 + 134{,}093 + 127{,}946 + 110{,}757 + 98{,}577 + 84{,}643 + 78{,}841 + 75{,}370 + 73{,}350 + 61{,}798 + 59{,}395$$

$$x^{(5)} = 1{,}196{,}493.$$

Obtained a projection calculation using the equation above, the total female population in the coming year is obtained, namely $x^{(1)} = 1{,}303{,}271$; $x^{(2)} = 1{,}291{,}715$; $x^{(3)} = 1{,}268{,}599$; $x^{(4)} = 1{,}238{,}043$; $x^{(5)} = 1{,}196{,}493$. From the calculation of the model that has been made to get the same final projection results as the previous calculation in equation (4), it can be noted that n(6) is the projection of the female population in West Jakarta City in 2028. The column vector can be rewritten into the following Table 4.

Table 4
Female population projection column vector result 2028

Age Interval (Years)	Female Population Projection 2028	Age Interval (Years)	Female Population Projection 2028
0-4	32,861	40-44	110,757
5-9	35,758	45-49	98,577
10-14	34,651	50-54	84,643
15-19	33,687	55-59	78,841
20-24	34,803	60-64	75,370
25-29	119,963	65-69	73,350
30-34	134,093	70-74	61,798
35-39	127,946	75+	59,395

Based on Table 4, it is obtained that the predicted female population in West Jakarta City in 2028 is 1,196,493 people. This indicates that there is a decrease in the number of female population of 102,908 people from 2023 to 2028.

3.5 Finding the Eigenvalues

The Leslie matrix that has been constructed above, then used in determining the eigenvalue can use equation (5). If A is an n×n matrix, then the following statements are equivalent to each other: λ is the eigenvalue of A.

$$det(\lambda I - A) = 0 \tag{5}$$

Equation $det(\lambda I - A) = 0$ is called the characteristic equation of A and is a polynomial of degree n [11].

$$\lambda I = \begin{bmatrix} \lambda & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \lambda & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \lambda & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \lambda & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \lambda & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \lambda & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \lambda & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & \lambda & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \lambda & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \lambda & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \lambda & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \lambda & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \lambda & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \lambda & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \lambda & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \lambda \end{bmatrix}$$

$$L = \begin{bmatrix} 0 & 0 & 0.0001 & 0.0046 & 0.0455 & 0.0951 & 0.0730 & 0.0375 & 0.0122 & 0.0009 & 0.0015 & 0 & 0 & 0 & 0 & 0 \\ 1.1155 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1.0355 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1.0328 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1.0579 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1.0957 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1.0354 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0.9744 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.9538 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.9529 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.9397 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.9143 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.8849 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.8608 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.9557 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1.0798 & 0 \end{bmatrix}$$

The eigenvalues are obtained as follows:

$\lambda_1 = 0; \lambda_2 = 0 ; \lambda_3 = 0; \lambda_4 = 0 ; \lambda_5 = 0; \lambda_6 = 0.861297244103331 ;$
$\lambda_7 = 0.469952928664940 + 0.629411427044775\, i;$
$\lambda_8 = 0.469952928664940 - 0.629411427044775\, i;$
$\lambda_9 = -0.559622370056473 + 0.149052337680395\, i;$
$\lambda_{10} = -0.559622370056473 - 0.149052337680395\, i;$
$\lambda_{11} = -0.112269896220287 + 0.584138788509020\, i;$
$\lambda_{12} = -0.112269896220287 - 0.584138788509020\, i;$
$\lambda_{13} = -0.342977412120909 + 0.465855635728704\, i;$
$\lambda_{14} = -0.342977412120909 - 0.465855635728704\, i;$
$\lambda_{15} = 0.114268127681065 + 0.267637295534589\, i;$
$\lambda_{16} = 0.114268127681065 - 0.267637295534589\, i.$

There are 16 eigenvalues that can be determined from a linear transformation in the form of a Leslie matrix L consisting of real and complex numbers. Then the largest eigenvalue is selected, namely $\lambda_6 = 0.861297244103331$. Then by using the approximation equation for the limiting age distribution, namely $\mathrm{x}^{\mathrm{k}} \approx \lambda_1 \mathrm{x}^{(\mathrm{k}-1)}$, so that $\mathrm{x}^{\mathrm{k}} \approx 0.8613\, \mathrm{x}^{(\mathrm{k}-1)}$. So, from the eigenvalues, we get $\lambda_1 < 1$ and it can be said that every year the population in West Jakarta City tends to decrease or it can be said that the population growth rate tends to be negative, which is 13.8703%.

Based on the research that has been done, it can answer the existing problem formulations. In the first problem formulation, it shows that the implementation of the Leslie matrix is able to project the number and growth rate of the female population in each age group, resulting in a female population in 2028 of around 1,196,493 people. Compared to the previous year, namely 2023, then in 2028 this has decreased. This can be caused by people who postpone marriage due to several factors including social, educational and career factors which make the population also decrease due to the lack of birth rate [12].

Furthermore, to answer the formulation of problem 2, namely after constructing the Leslie matrix model, the eigenvalue calculation is carried out with the limiting age distribution, the results show the eigenvalue $\lambda_1 < 1$. So, it can be said that every year the population in West Jakarta City tends to decrease or it can be said that the population growth rate tends to be negative, which is equal to 13.8703 %, then it can be concluded that the female population in 2028 has decreased. The results of this study are supported by Sugara and Arnellis [13] shows that the number and rate of female population for the next two years, namely 2022, has decreased from the previous year, characterized by eigenvalue $\lambda_1 < 1$. However, this is inversely proportional to the research [14] which shows the population growth rate of West Java Province can fluctuate but has an increasing trend based on the dominant eigenvalue greater than one and in research [15] shows that the population growth rate in

2027 increases from the previous year's eigenvalue because the dominant eigenvalue is obtained, namely $\lambda = 1.23 > 0$.

Furthermore, for problem formulation 3 regarding government programs that must be mapped to the population based on age range. By using the Leslie Matrix model, the prediction of the number of female population who can support and participate in the programs of the DKI Jakarta Provincial Government with their respective age classes in 2028 is as follows: Child Rights Fulfillment Program (136,957), Toddler Family Development (68,619), Adolescent Family Development (103,141), Elderly Family Development (433,757), Youth Information and Consultation Center (33,687), Gender Mainstreaming and Women's Empowerment Program (154, 766), Family Quality Improvement Program (591,336), Family Planning Development Program (626,139), Family Welfare Empowerment and Improvement Program (591,336), Generation Planning Forum (103,141), West Jakarta Children's Forum (136,957), Family Learning Center (527,562).

4. Conclusions

Based on the results of research and data analysis using the Leslie matrix model on the female population in West Jakarta City, it can be concluded that:

(1) The eigenvalue obtained from the Leslie matrix with the help of the Python programming language is 0.8613 for the limiting age distribution approach value, namely $x^k \approx 0.8613\, x^{(k-1)}$. So it can be seen that every year the number of births has decreased, namely in 2024, 2025, 2026, 2027, and 2028. It can be concluded that the number of female population decreased in 2028 and it can be said that the population growth rate in West Jakarta City tends to be negative, which is 13.8703%.

(2) The following results of the projection of the number of women in 2028 were obtained :
$x^{(5)} = 32{,}861 + 35{,}758 + 34{,}651 + 33{,}687 + 34{,}803 + 119{,}963 + 134{,}093 + 127{,}946 + 110{,}757 + 98{,}577 + 84{,}643 + 78{,}841 + 75{,}370 + 73{,}350 + 61{,}798 + 59{,}395 = 1{,}196{,}493$

5. Sugestion

In this final project, the author only predicts the number of births and the growth rate of the female population for mapping women's development programs in West Jakarta City using the Leslie matrix model calculation. So that for further research, researchers can predict the number of population births outside DKI Jakarta and also use other parameters such as mortality rates.

Acknowledgement

This research was not funded by any grant.

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