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Analysis of the Impact of Population Growth in DKI Jakarta Using Logistic Model

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Abstract

The rapid population growth in the DKI Jakarta area has an impact on its population and creates an unfriendly environment. The author is motivated to analyse the effect of the population growth rate in DKI Jakarta over the next 10 years. The process of estimating population growth is calculated by a mathematical model called the logistic model. The logistic model is the model that developed by differential equation like the following $\frac{dN}{dt} = N\ (a - bN)$. This model illustrates that population growth is determined by the difference between the number of births and deaths of the population. In addition, an analysis of the resulting environmental impact and the impact of its handling will also be discussed. Based on estimation, the population in DKI Jakarta Province in 2022 is predicted around 10,636.685 people and it will reach 10,938.900 in 2030. It means there will be a 3% increase in population from 2019 to 2030 in DKI Jakarta Province. These values increase annually and they are predicted to have an impact on increasing the traffic congestion by 3%, from 70% to 72.1%. Another result has also occurred in air pollution. The average of air pollution increasing by 3%, from 39.6 $\mu g/m^3$ to 40.79 $\mu g/m^3$. These two factors show that the increase of population growth will have an impact on increasing the average traffic congestion and the percentage of air pollution in DKI Jakarta.

Keywords: Logistic Model; Population Growth; Social Impact

Abstrak

Pertumbuhan penduduk yang sangat pesat di wilayah DKI Jakarta memiliki dampak pada populasinya serta menciptakan lingkungan yang kurang ramah. Hal ini memotivsi penulis untuk menganalisis dampak dari laju pertumbuhan penduduk di DKI Jakarta selama 10 tahun mendatang. Proses estimasi pertumbuhan penduduk dikalkulasi mengunakan pemodelan matematika yang bernama model logistik.Model logistik adalah sebuah model matematika yang dikembangkan

menggunakan persamaan differensial sebagaimana berikut $\frac{dN}{dt} = N\ (a - bN)$. Model logistik mengilustrasikan pertumbuhan populasi penduduk sebagai selisih antara jumlah populasi yang lahir dengan jumlah populasi yang meninggal. Selain itu juga, akan dipaparkan mengenai dampak pencemaran lingkungan yang mungkin akan muncul di waktu yang akan datang. Berdasarkan hasil estimasi diperoleh prediksi jumlah penduduk di Provinsi DKI Jakarta pada tahun 2022 sebanyak 10,636.685 jiwa dan pada tahun 2030 akan mencapai 10,938.900. Hal tersebut berarti akan ada peningkatan sekitar 3% penduduk dari tahun 2019 hingga tahun 2030 di Provinsi DKI Jakarta. Nilai pertumbuhan populasi tersebut meninggkat setiap tahunnya dan diprediksi dapat meningkatkan kepadatan lalu lintas sebesar 3%, dari 70% menjadi 72.1% di tahun 2030. Hasil lain yang diprediksi akan terjadi ialah peningkatan rata-rata polusi udara sebesar 3%, dari 39.6 $\mu g/m^3$ menjadi 40.79 $\mu g/m^3$ pada tahun 2030. Kedua faktor ini menunjukan bahwa peniongkatan jumlah populasi penduduk di Provinsi DKI Jakarta dapat memberikan dampak pada peningkatan rata-rata kepadatan kendaraan dan polusi udara di Provinsi DKI Jakarta.

Kata Kunci: Dampak Sosial; Model Logistik; Pertumbuhan Penduduk

Introduction

DKI (Special Capital Region) Jakarta Province is the capital city of the country which is the center of the economy and government (Zhu & Simarmata, 2015; Syalianda & Kusumastuti, 2021; Shatkin, 2022). As a result, many people are competing to come into Jakarta and look for work. Based on data from the Central Agency of Statistics, in 2021 the total population in DKI Jakarta reached 20 million people. The data is spread over five districts and cities such as: Kepulauan Seribu, Jakarta Selatan, Jakarta Timur, Jakarta Pusat, Jakarta Barat, dan Jakarta Utara (Yoo, Kim, & Hadi, 2014; Kamh, Khalifa, & El-Bahrawy, 2016; Heidrich, Jayathunga, Bock, & Götz, 2021; Rukmana, & Ramadhani, 2021). If the data is compared to area which have 662.33 km^2, the result is a very high population density. For five districts and cities in DKI Jakarta, the population density data for each city in 2021 are as follows: 2774, 14475, 16729, 20360, 19608, 12749, and 15978 per km^2 ("BPS Provinsi DKI Jakarta," n.d.).

Furthermore, mathematical modeling is carried out to help solve this problem. The logistic model is used to estimate population growth in DKI Jakarta over the next 10 years. This model was chosen because of its algorithm to model growth rates as in the following research such as Grey Prediction Model of Population Growth (Tong, Yan, & Chao, 2020), Fractional Numerical Dynamics For Logistic Population (Qureshi, Yusuf, & Aziz, 2021), A Closed-Form Solution to The Ramsey Model with Logistic Population Growth (Guerrini, 2010), and Logistic Population in The World's Largest Cities (Mulligan, 2006; Chen, 2014; Hsieh, 2014; Vieira, Hiar, & Cardoso, 2022). In this paper, we used a logistic model to model

population growth in DKI Jakarta province and analyzed the impact on the social sector.

The social sectors have been discussed in this paper are traffic problems and air pollution levels. We compared the results of the estimated population in DKI Jakarta with these two variables. The results of the analysis are presented in graphical form and the recommendations are given to each of the following problems with graphical analysis to obtain the solutions of the problems.

In the next section, we will discuss the method and the results. the method used is mathematical modeling related to the field of biology. The logistic model can explain the growth of an object by using the differential equation. The idea is to consider the difference between the birth rate and the death rate of the object. the result is obtained by estimating the rate of population growth and calculating the analytical solution from the logistic model.

Method

The method used in this study is mathematical modeling using a logistic model as described in (Pagalay, 2009).

$$\frac{dN}{dt} = N\left(a - bN\right) \tag{1}$$

We will derive the analytical solution of Equation 1. Integrate both sides to get

$$\Leftrightarrow \int_{t_0}^{t_1} \frac{dN}{N\left(a-bN\right)} = \int_{t_0}^{t_1} dt$$

$$\Leftrightarrow \int_{t_0}^{t_1} \left(\frac{1/a}{N} dN \right) + \int_{t_0}^{t_1} \left(\frac{b/a}{a-bN} dN \right) = \int_{t_0}^{t_1} dt$$

$$\Leftrightarrow \frac{1}{a}\left[\ln \frac{\left|N\left(t_1\right)\right|}{\left|N\left(t_0\right)\right|} + \ln \frac{\left|a-bN\left(t_0\right)\right|}{\left|a-bN\left(t_1\right)\right|} \right] = t_1 - t_0$$

By taking the logarithmic property we get

$$\Leftrightarrow \ln\left(\frac{\left|N\left(t_1\right)\right|}{\left|N\left(t_0\right)\right|} \right)\left(\frac{\left|a-bN\left(t_0\right)\right|}{\left|a-bN\left(t_1\right)\right|} \right) = a\left(t_1 - t_0\right)$$

$$\Leftrightarrow \left(\frac{\left|N\left(t_1\right)\right|}{\left|N\left(t_0\right)\right|} \right)\left(\frac{\left|a-bN\left(t_0\right)\right|}{\left|a-bN\left(t_1\right)\right|} \right) = e^{a\left(t_1 - t_0\right)}$$

For each t_1 elements times T and $N(t_0) = N_0$, we get the analytic solution for Equation 1 as follows:

$$N(t) = \frac{aN_0 e^{a(t_1 - t_0)}}{a - bN_0 + bN_0 e^{a(t_1 - t_0)}} \tag{2}$$

With $N(t)$ respect to the population growth at times t, N_0 respect to the initial condition, a and b respect to the bird and death rate. We assume K is the maximum growth, then a will decrease as $N(t)$ approaches K and will be negative if $N(t)$ exceeds K. As this result we can modify Equation (2) become Equation (3) as follows:

$$N(t) = \frac{N_0 K}{N_0 + (K - N_0) e^{-a(t_1 - t_0)}} \tag{3}$$

The population described in equation 3 is DKI Jakarta residents.

Results

Population data for the last three years is used to determine the rate of growth and is attached to Table 1 (data in thousand units) ("BPS Provinsi DKI Jakarta," n.d.).

Table 1. The Population of DKI Jakarta from 2019 to 2021

Cities	2019	2020	2021
Kepulauan Seribu	24.3	27.75	28.24
Jakarta Selatan	2264.7	2226.81	2233.86
Jakarta Timur	2937.86	3037.14	3056.3
Jakarta Pusat	928.11	1056.9	1066.46
Jakarta Barat	2589.93	2434.51	2440.07
Jakarta Utara	1812.91	1778.98	1784.75
DKI Jakarta	10557.81	10562.09	10609.36

The birt rate a will be derived from Equation 1 as follows.

$$\ln(N(t)) - \ln(N_0) = a(t - t_0)$$
$$\Leftrightarrow a = \frac{\ln(N(t)) - \ln(N_0)}{(t - t_0)} \tag{4}$$

According to Table 1 and Equation (4) we can get $a = 0.004465455$.

Furthermore, the population of DKI Jakarta from 2022 to 2030 will be estimated using the values of $a = 0.004465455$, $t_0 = 2020$, $K = 50000$ and Equation (3) as follows

$$N(2022) = \frac{(10562.09).(50000)}{10562.09 + (50000 - 10562.09)e^{-0.004465455(2022-2020)}} = 10636.685 \quad (5)$$

$$N(2023) = \frac{(10562.09).(50000)}{10562.09 + (50000 - 10562.09)e^{-0.004465455(2023-2020)}} = 10674.126 \quad (6)$$

$$N(2024) = \frac{(10562.09).(50000)}{10562.09 + (50000 - 10562.09)e^{-0.004465455(2024-2020)}} = 10711.663 \quad (7)$$

$$N(2025) = \frac{(10562.09).(50000)}{10562.09 + (50000 - 10562.09)e^{-0.004465455(2025-2020)}} = 10749.297 \quad (8)$$

$$N(2026) = \frac{(10562.09).(50000)}{10562.09 + (50000 - 10562.09)e^{-0.004465455(2026-2020)}} = 10787.026 \quad (9)$$

$$N(2027) = \frac{(10562.09).(50000)}{10562.09 + (50000 - 10562.09)e^{-0.004465455(2027-2020)}} = 10824.850 \quad (10)$$

$$N(2028) = \frac{(10562.09).(50000)}{10562.09 + (50000 - 10562.09)e^{-0.004465455(2028-2020)}} = 10862.771 \quad (11)$$

$$N(2029) = \frac{(10562.09).(50000)}{10562.09 + (50000 - 10562.09)e^{-0.004465455(2029-2020)}} = 10900.788 \quad (12)$$

$$N(2030) = \frac{(10562.09).(50000)}{10562.09 + (50000 - 10562.09)e^{-0.004465455(2030-2020)}} = 10938.900 \quad (13)$$

The Equation (5) to (13) are presented in form of a table and graph as follows.

Table 2. Estimated Population of DKI Jakarta (Data in Thousand Units).

Years	Estimated Population
2022	10636.685
2023	10674.126
2024	10711.663
2025	10749.297
2026	10787.026
2027	10824.850
2028	10862.771
2029	10900.788
2030	10938.900

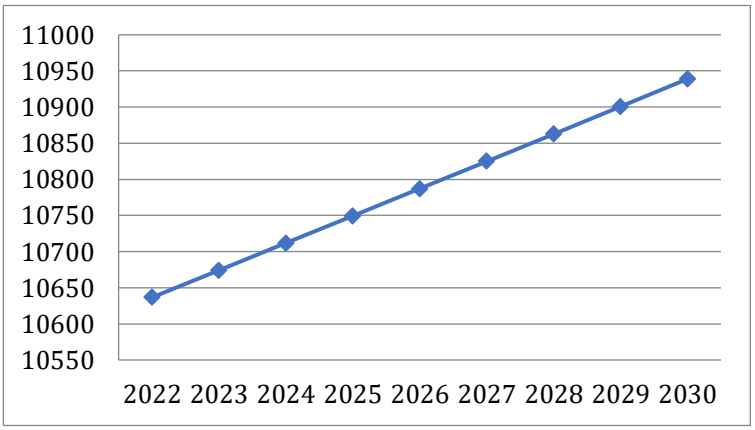

Figure 1. Estimated Population Growth in DKI Jakarta

According to Table 2 and Figure 1, the estimated estimated population growth in DKI from 2022 to 2030 are 10,636,685; 10,674,126; 10,711,663; 10,749,297; 10,787,026; 10,824,850; 10,862,771; 10,900,788; and 10,938,900. These values increase from year to year.

Discussion

The traffic index stated the average congestion of DKI Jakarta in 2019 is 70% ("Jakarta Traffic Report | TomTom Traffic Index," n.d.). Based on Table 1 the population in 2019 is 10,557.810. On the other hand, the estimated population in 2030 is 10,938.900. there will be a 3 percent increase in population from 2019 to 2030. This means the traffic congestion in 2030 may increase to reach 72.1%.

In Figure 2 we can see the average of air pollution in DKI Jakarta. The data are taken from ("Kota Paling Berpolusi Di Dunia 2021 - Rangking PM2.5 | IQAir," n.d.).

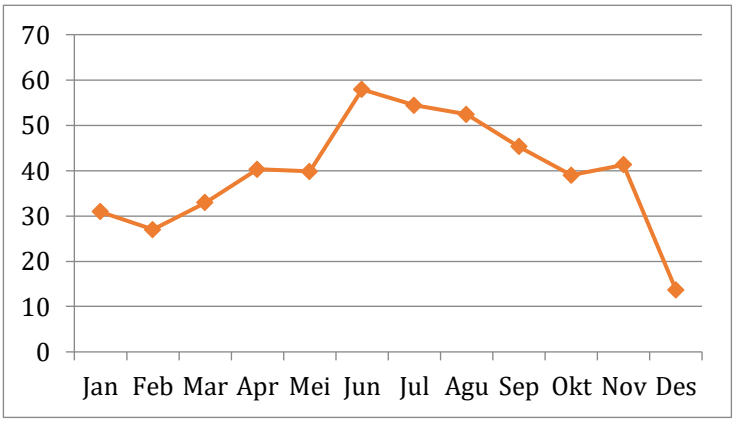

Figure 2. Air pollution Index in DKI Jakarta ($\mu g/m^3$)

In Figure 2 the air pollution index is given. From January to December 2020 the values are 30.9; 27; 32.9; 40.3; 39.8; 57.9; 54.4; 52.4; 45.3; 39; 41.3; and 13.7. So, the average air population index is 39.6 $\mu g/m^3$. Based on Table 1 the population in 2020 is 10,562,090. On the other hand, the estimated population in 2030 is 10,938,900. There will be a 3 percent increase in population from 2019 to 2030. This means that the average air pollution index may increase to 40.79 $\mu g/m^3$.

This study provides an overview of the increasing population in the province of DKI Jakarta over the next ten years and provides caution of the social impacts. This paper tries to provide alternative solutions to prevent these undesirable impacts. As discussed by (Jacobson, 2009) regarding the use of nine alternative sources of electrical energy such as electricity sources include solar-photovoltaics (PV), concentrated solar power (CSP), wind, geothermal, hydroelectric, wave, tidal, nuclear, and coal with carbon capture and storage (CCS) technology and the use of two alternative liquid fuel sources such as include corn-ethanol (E85) and cellulosic-E85. In addition, the considerable efforts to reduce carbon dioxide levels are necessary. As the study conducted by (Rachim & Firdaus, 2021), CO_2 levels can increase the temperature.

Some possible solutions for traffic jams such as considering the presence of trucks crossing the main road as discussed by (Rachim, Salmah, & Solekhudin, 2017) and applying control signals in the form of variable speed limit and ramp metering to regulate vehicle entry and exit flows as reviewed by (Hajiahmadi et al., 2016).

Conclusion

The logistic model has been formulated in Equations (1), (2), and (3). We estimated the population growth of DKI Jakarta from 2022 to 2030 using equation (3). The result are 10,636,685; 10,674,126; 10,711,663; 10,749,297; 10,787,026; 10,824,850; 10,862,771; 10,900,788; and 10,938,900. These values increase annually and they are predicted to have an impact on increasing the traffic congestion by 3%, from 70% to 72.1%. The another result has also occurred in air pollution. The average of air pollution increasing by 3%, from 39.6 $\mu g/m^3$ to 40.79 $\mu g/m^3$. This study provides an overview of the increasing population in the province of DKI Jakarta over the next ten years and provides caution of the social impacts. This paper suggests alternative solutions such as the use of nine alternative sources of electrical energy: electricity sources include solar-photovoltaics (PV), concentrated solar power (CSP), wind, geothermal, hydroelectric, wave, tidal, nuclear, and coal with carbon capture and storage (CCS) technology and the use of

two alternative liquid fuel sources: corn-ethanol (E85) and cellulosic-E85 to prevent these undesirable impacts.

This paper also give suggestion to solve traffic congestion, such as considering the presence of trucks crossing the main road and applying control signals in the form of variable speed limit and ramp metering to regulate vehicle entry and exit flows Further research can be developed by further observing the existing data and can also be applied to all regions in Indonesia.

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