

MODELING OF LABOR MARKET DYNAMICS IN BALIKPAPAN USING THE LOGISTIC GROWTH MODEL

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ABSTRACT

Population growth and labor force dynamics become important issues in development planning, especially in the buffer zone of the National Capital City (IKN) such as Balikpapan City. This study aims to model the dynamics of labor market in Balikpapan City using Verhulst logistic growth model approach. The data used includes the number of labor force and non-labor force in the period of 2007 to 2023, obtained from the Central Bureau of Statistics of East Kalimantan Province. The modeling process is conducted independently to ensure analytical clarity between labor force and non-labor force groups to obtain a more accurate projection. The results of the analysis show that the average population of the labor force is 289,631 people with a growth rate of 7.17%, while the non-labor force has an average of 156,643 people with a growth rate of 4.44%. Model validation showed a coefficient of determination (R^2) of 0.87 for the labor force and 0.88 for the non-labor force, indicating a good model fit. The difference in growth rate reflects the potential improvement of labor market condition in Balikpapan City. The findings of this study are expected to be a reference for the government and policy makers in formulating strategies for improving the quality of human resources and inclusive and sustainable employment planning in the buffer zone of IKN.

Keywords: Logistic Model, Labor Market Dynamic, Population Growth, Balikpapan City, Labor and Non-Labor Force

ABSTRAK

Pertumbuhan penduduk dan dinamika angkatan kerja menjadi isu penting dalam perencanaan pembangunan, terutama di wilayah penyangga Ibu Kota Negara (IKN) seperti Kota Balikpapan. Penelitian ini bertujuan untuk memodelkan dinamika pasar tenaga kerja di Kota Balikpapan dengan pendekatan model pertumbuhan logistik Verhulst. Data yang digunakan meliputi jumlah angkatan kerja dan bukan angkatan kerja pada periode 2007 hingga 2023, yang diperoleh dari Badan Pusat Statistik Provinsi Kalimantan Timur. Pemodelan dilakukan secara terpisah antara kelompok angkatan kerja dan bukan angkatan kerja untuk memperoleh proyeksi yang lebih akurat. Hasil analisis menunjukkan bahwa rata-rata populasi angkatan kerja adalah 289.631 jiwa dengan laju pertumbuhan sebesar 7,17%, sedangkan bukan angkatan kerja memiliki rata-rata 156.643 jiwa dengan laju pertumbuhan 4,44%. Validasi model menunjukkan nilai koefisien determinasi (R^2) sebesar 0,87 untuk kelompok angkatan kerja dan 0,88 untuk bukan angkatan kerja, yang mengindikasikan kesesuaian model yang baik. Perbedaan laju pertumbuhan ini mencerminkan potensi perbaikan kondisi pasar tenaga kerja di Kota Balikpapan. Temuan penelitian ini diharapkan dapat menjadi acuan bagi pemerintah dan pemangku kebijakan dalam merumuskan strategi peningkatan kualitas sumber daya manusia dan perencanaan ketenagakerjaan yang inklusif dan berkelanjutan di kawasan penyangga IKN.

Kata kunci: Model Logistik, Dinamika Pasar Tenaga Kerja, Pertumbuhan Populasi, Kota Balikpapan, Angkatan Kerja dan Bukan Angkatan Kerja

INTRODUCTION

Balikpapan is a municipal administrative region in the province of East Kalimantan and is one of the largest cities in the province after the capital city of Samarinda with a population predicted in 2025 to reach 809,294 people (1). As a big city, Balikpapan is also famous for being one of the cities of multisectoral industries such as manufacturing, construction and trade with a Gross Regional Domestic Product of 83,604,887.63 Indonesian Rupiah in 2019 (2). In addition, the city of Balikpapan is also one of the buffer areas of the ambitious project of the State Capital of the Nusantara in accordance with the Law of the Republic of Indonesia Number 3 of 2022 concerning the State Capital along with several districts such as Penajam Paser Utara and Kutai Kartanegara (3). In addition to being a multi-sector industrial city, Balikpapan's strategic position as a logistics and transportation hub in Kalimantan makes it an important transit area for the flow of goods, services and people. The city is experiencing rapid development dynamics, especially after the announcement of the relocation of the National Capital City or *Ibu Kota Nusantara (IKN)* to the East Kalimantan region. This phenomenon is expected to have a direct impact on the population and employment structure of Balikpapan, which is the main buffer zone of the national development activities.

Cities with larger populations tend to face more diverse social, economic, and demographic issues. Classifying the population into working-age (15–64 years) and non-working-age groups helps explain the varying needs and dynamics within the population. In the working age group, it is further divided into two groups, namely the Labor force and the non-Labor force. The Labor force is the population that has a job or is temporarily unemployed, while the

non-Labor force is the population in the working age group that is not working or not actively looking for work due to many reasons such as still in school or taking care of the household or doing personal activities (4). This condition becomes even more important when associated with the direction of national development that focuses on economic transformation and strengthening the competitiveness of human resources. Along with the development of the *IKN* area and various other national strategic projects in East Kalimantan, the need for accurate labor data and projections is increasing.

Therefore, the study of the structure and dynamics of the labor force is an important foundation in evidence-based planning for regional development. The Labor force plays a significant role in driving economic growth, especially through improving the quality of human resources as measured by the Human Development Index (HDI). Studies show that HDI contributes directly and indirectly to economic growth by increasing the productivity of the Labor force through better access to education, health and infrastructure. Although demographic pressures and the happiness index affect socio-economic conditions, their effect on economic growth is not as great as the HDI.

Therefore, policies that focus on improving the quality of life of the Labor force, such as investments in education and health, are essential to ensure the optimal contribution of the Labor force to sustainable economic growth (5). Other research suggests that educated Labor force participation has a significant effect on economic growth with a significance level of 5%. The distribution includes the primary and advanced educated Labor force which are significant in the long and short-term periods, while the secondary educated Labor force is only significant in the long-term period (6). This proves that the Labor

force and non-Labor force have an important role in the growth and determination of economic conditions in a region.

The growth of a population can be simulated mathematically with a population ecology model. This biomathematical model, which is very often used, is the Lotka-Volterra model, which is quite dynamic because it is influenced by the interaction between “predators” and “prey”(7,8). A simpler analysis is logistic function can be used by assuming interactions. The logistic growth model is a mathematical model that describes the growth of a population or number of individuals in a resource-constrained system. This model describes how a population grows rapidly at first, but then the growth rate slows down as the population density increases and the available resources are limited. Logistic models have proven to be very good at describing population growth.

Previous research compared the exponent model and the logistic model to describe the population of Surabaya city based on data from the Population and Civil Registration Office from 2011 to 2015. The results showed that the logistic model is superior to the exponential model characterized by the smallest error value or the logistic model is closer to the actual data (9). In another case, the modified logistic model was used to estimate the growth of deaths due to COVID-19 and was applied for forecasting the outbreak in the third wave of the pandemic in South Africa (10).

Amid the need for precise and science-based projections, mathematical modeling is one promising approach. Logistic models, in particular, have proven to be reliable in describing population growth by considering the upper limit or carrying capacity of a system. Its advantage lies in its ability to show realistic long-term dynamics - in contrast to exponential models that tend to be infinite and less appropriate in the context of limited resources.

Based on the previous explanation, logistic growth modeling can be applied to predict the growth of Labor force and non-Labor force in a region, which means it can describe the dynamics of Labor market that also reflects the economic condition in that location. This study aims to model the growth of the labor force and the non-labor population in Balikpapan City using a logistic approach. The results are intended to support the government and relevant stakeholders in formulating actions related to population dynamics as an initial step toward improving the welfare of the city's residents.

METHODS

This research is conducted by taking data on the number of Labor force and non-Labor force in Balikpapan city from 2007 to 2023 sourced from the Central Bureau of Statistics of East Kalimantan Province. The data obtained is processed and presented following the method described in this section.

Logistic Distribution Model

The distribution model uses logistic distribution. This distribution model was chosen because the research conducted will focus on the logistic growth model which results in the distribution of probabilities also as much as possible in logistic form. The Cumulative Distribution Function (CDF) and Probability Density Function (PDF) for the logistic distribution can be expressed as follows (11–13):

$$F(x; \mu; s) = \frac{1}{1 + e^{-\frac{x-\mu}{s}}} \quad [1]$$

$$\begin{aligned} f(x; \mu; s) &= \frac{\partial}{\partial x} F(x; \mu; s) \\ &= \frac{e^{-\frac{x-\mu}{s}}}{s \left(1 + e^{-\frac{x-\mu}{s}}\right)^2} \end{aligned} \quad [2]$$

Where $F(x; \mu; s)$ is cumulative distributions function. $f(x; \mu; s)$ is probability density

function. x is dependent variable, μ is center of distribution (mean/ median/ mode). s is a scale parameter proportional to the standard deviation.

Logistic Population and Growth Model

Population growth was conducted on two groups: the Labor force (LF) and the non-Labor force (NLF). The two groups are modelled without any interaction, which means that each group grows independently and has no dependence on each other. This is done to simplify the analysis and simplify the method of finding each determining variable. The population and logistic growth model follows the Verhulst model as follows (14–19):

$$P(t) = \frac{K}{1 + \left(\frac{K - P_0}{P_0}\right) e^{-rt}} \quad [3]$$

$$\frac{dP}{dt} = rP \left(1 - \frac{P}{K}\right) \quad [4]$$

Where $P(t)$ is a function that describes the population over time. $\frac{dP}{dt}$ is the first derivative of the population function with respect to time which describes the rate of population change. K is the carrying capacity which is the upper limit of the population. P_0 is the initial population of observations. r is intrinsic growth rate. t is observation time. P is the population at time t . For simplicity and ease of modeling, the K value is assumed to be twice the mean obtained from the logistic distribution model analysis. This is reasonable under relatively stable population conditions that oscillate around half the carrying capacity. As for the value of r , it is assumed to be the same over time, which is obtained from the optimization carried out with the help of a solver in the Excel program.

Labor Market Dynamics Model

The dynamics of the labor market are fully seen from the rate of change in the Labor force and non-Labor force

populations. Labor market conditions can be said to be good if the rate of change in the Labor force population is greater than the rate of change in the non-Labor force population. Conversely, if the rate of change of the non-Labor force population is greater than the rate of change of the Labor force population, this indicates that the Labor market dynamics are not good. This indicates that the economy is experiencing a downturn. If the difference between the two is equal to zero, this indicates that there is a Labor market equilibrium or can be said to be a transition period. Mathematically, Labor market dynamics based on the growth rate of the Labor force and the growth rate of the non-Labor force can be expressed as follows;

$$\frac{dLM}{dt} = \frac{dLF}{dt} - \frac{dNLF}{dt} \quad [5]$$

Where $\frac{dLM}{dt}$, $\frac{dLF}{dt}$, $\frac{dNLF}{dt}$ is the rate of change of the Labor market, the rate of change of the Labor force population and the rate of change of the non-Labor force population, respectively. $\frac{dLF}{dt}$, $\frac{dNLF}{dt}$ obtained based on equation 4 by replacing P with the function of each population of each group.

RESULT

Logistics Distribution Analysis

Logistic distribution analysis was conducted separately between the Labor force and non-Labor force groups. There are a total of 17 population data in each group, sorted from smallest to largest population size. The analysis was carried out with the aim of seeing how the data was spread, looking at the probability density and looking at the center of the distribution. Figure 1 illustrates the cumulative distribution (CD) of the Labor force group and Figure 2 illustrates the CD for the non-Labor force group.

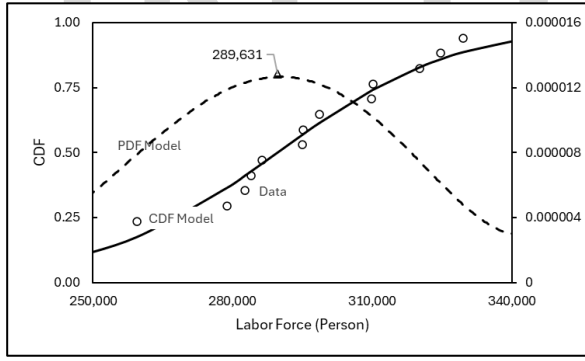


Figure 1. CD of labor force

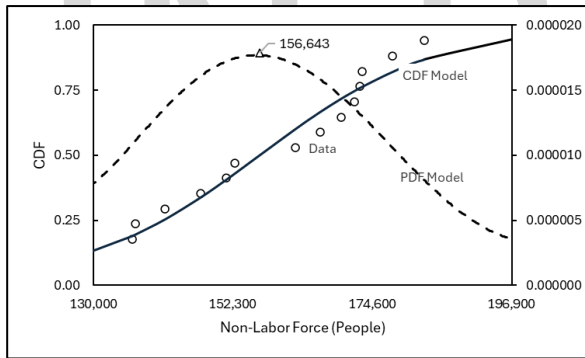


Figure 2. CD of non-labor force

Figure 1 and Figure 2 display the CD of each group, the PD bell curve is quite gentle with a peak of only 0.000013 for the Labor force group and 0.000018 for the non-Labor force group. This slope indicates that the data is very widely spread with a large variance. This is indicated by the s value of 19,460.923 people for the Labor force group and 13,992.874 people for the non-Labor force group, where the s value can be calculated as in equation 6. The mean value of each PD curve is 289,631 people for the Labor force group and 156,643 people for the non-Labor force group. These figures will be used to calculate the carrying capacity in the next analysis.

$$\text{Peak of PDF} = f(\mu) = \frac{1}{4s} \quad [6]$$

Population and Growth Model

Population and growth in this case is the rate of change following the Verhulst model described in equation 3 and equation 4 which requires the parameters K and r respectively. The value of K as explained earlier is twice the average value rounded

up which means the value of K for the Labor force and non-Labor force groups is 579,261 people and 313,286 people respectively with the initial population from the observation in 2007 of 197,991 people for the Labor force group and 136,210 people for the Non-Labor force group. The value of r is obtained from solver-assisted optimization with an indication of the best R^2 value between the real population data and the model. The value of r for each group is 7.17% for the Labor force group and 4.44% for the non-Labor force group. From the parameters obtained, the population function and population change rate for each group were formed as follows:

$$LF(t) = \frac{579,261}{1 + (1.93)e^{-0.0717t}} \quad [7]$$

$$\frac{dLF}{dt} = 0.072LF \left(1 - \frac{LF}{579,261} \right) \quad [8]$$

$$NLF(t) = \frac{313,286}{1 + (1.30)e^{-0.0444t}} \quad [9]$$

$$\frac{dNLF}{dt} = 0.044NLF \left(1 - \frac{NLF}{313,286} \right) \quad [10]$$

Equations 7 and 8 can be presented in graphical form as shown in Figures 3, 4, 5 and 6.

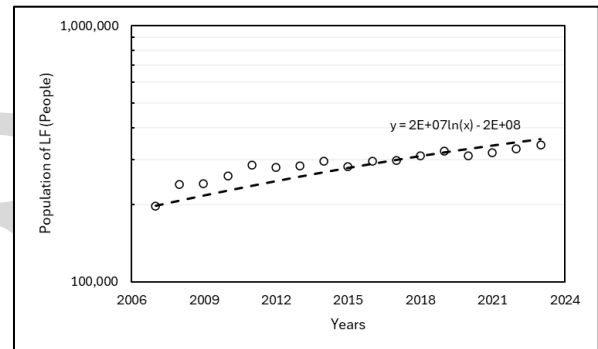


Figure 3. LF Regression with Verhulst Model

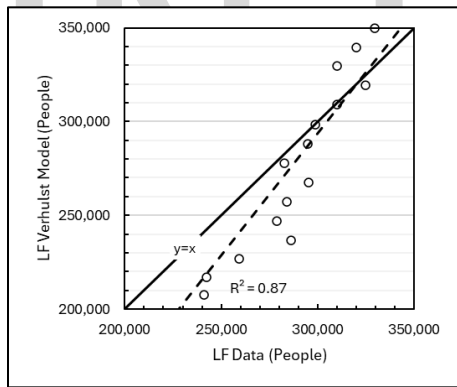


Figure 4. Validation of LF Model

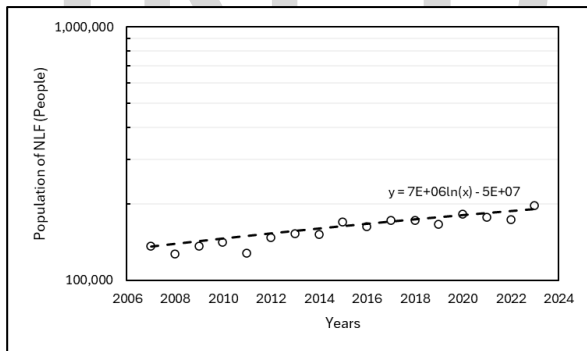


Figure 5. NLF Regression with Verhulst Model

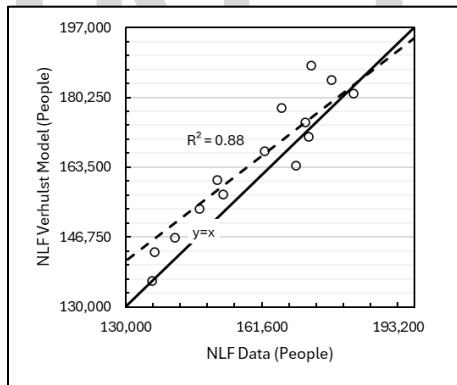


Figure 6. Validation of NLF Model

Figure 3, Figure 4, Figure 5 and Figure 6 present the regression of population change for each group and the validation of the Verhulst model using data obtained from the East Kalimantan Provincial Statistical Center. During data validation, the R^2 value is considered quite good, reaching 0.87 for the Labor force group and 0.88 for the non-Labor force group. The regression between the model and the data from each group was made in

logarithmic form with the equation $y = 2E+07\ln(x) - 2E+08$ for the regression on the Labor force model and $y = 7E+06\ln(x) - 5E+07$ for the non-Labor force model. If we trace the equation, we can predict the population in the following years based on the equation obtained from the Verhulst model. These equations are useful for the analysis of Labor market dynamics that will be discussed later.

Labor Market Dynamics Analysis

The dynamics of the Labor market can be seen from the rate of change in the population of each disputed group as illustrated in equation 5. The population change of each group can be seen in Figure 7.

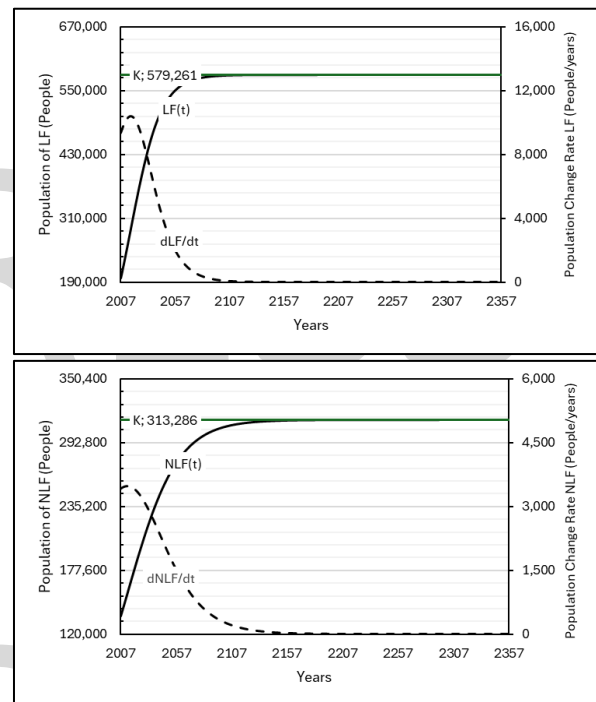


Figure 7. Change and Rate of Change of Population of Each Group

Figure 7 shows the graphs of $LF(t)$ and $NLF(t)$ as asymptotic sigmoid with green lines spanning the 350 years of observation, from 2007 to 2357. The green line represents the carrying capacity of each group, assumed to be twice the average. The bell curve with a dashed line illustrates the rate of change in each group's population,

which continues asymptotically toward the x-axis. This suggests that change will persist but will gradually approach zero. The divergence of the dotted line curves reflects the dynamics of the Labor market at any given time, which is further illustrated in Figure 8.

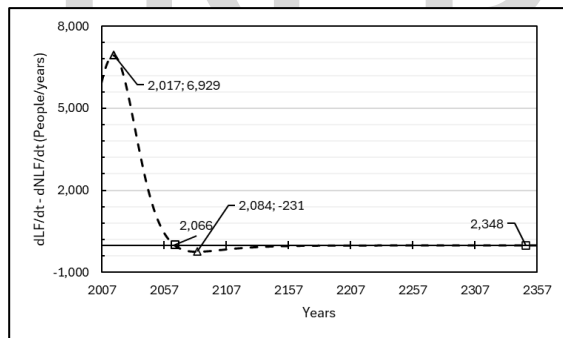


Figure 8. $\frac{dLF}{dt} - \frac{dNLF}{dt}$ graph

Figure 8 presents a graph of the difference between the growth rate of the labor force (LF) and the non-labor force (NLF), which is interpreted as an indicator of long-term labor market dynamics. The curve is bell-shaped, depicting the phases of structural change of productive population in Balikpapan City. At the beginning of the observation period, i.e. around 2007 until the mid-2060s, the curve is above the horizontal axis, indicating a labor surplus phase, i.e. when the growth of the labor force is higher than that of the non-labor force. The peak of the surplus occurs in 2017 with a difference of almost 7,000 people per year. After that, the curve declines and reaches zero around 2066, which marks the transition phase of the balance between labor supply and demand. From 2084 onwards, the curve moves downward, signaling a labor deficit phase, in which the number of active working-age people decreases faster than the group not participating in the labor market.

DISCUSSION

These phases have significant strategic implications. In the surplus phase, the demographic bonus opportunity is wide open, which in development economics literature is considered a golden momentum for sustainable economic growth. However, this bonus can only be achieved if it is accompanied by an improvement in the quality of the workforce, the provision of adequate employment, and targeted policy

support. Without this, this surplus has the potential to cause mass unemployment, social inequality, and an increase in the government's fiscal burden. Conversely, in the deficit phase, the challenge shifts to labor scarcity, which can lead to increased labor costs, slowing productivity, and delays in infrastructure and industrial projects, especially in the context of the development of the National Capital City which will require a large and sustainable supply of labor.

The transition between the three phases occurs gradually, as illustrated by the logistic curve that is asymptotic to time. As a result, early policy interventions are crucial in regulating the rate of labor market change to ensure it remains within a stable and manageable range. During the equilibrium phase (around 2066), the government can work to stabilize the employment system by aligning the education, industry, and public service sectors to operate synergistically. This phase also presents an ideal opportunity to evaluate the effectiveness of human resource development programs and to adjust the education curriculum to meet the demands of future industries, particularly in the areas of technology, renewable energy, and the digital economy.

However, it is important to note that the logistics model used in this study has not considered dynamic external factors such as massive migration due to the relocation of the capital city, global economic fluctuations, changes in industrial patterns, digital transformation, and the climate crisis. These factors can accelerate or even reverse the direction of the labor market dynamics projected by the model. Therefore, this modeling needs to be complemented with sensitivity analysis and alternative scenarios to provide a more adaptive picture of future uncertainties.

The graph of the difference in growth rates between the labor force and the non-labor force, in this context, functions not only as a demographic projection tool but

also as an early warning system for regional employment and economic development policies. Local and national governments can leverage this information as a foundation for data-driven policy-making—ranging from the formulation of employment strategies and vocational training programs to the development of industrial estates and the provision of incentives for the private sector to absorb local labor. Through a holistic and responsive approach, the findings of this research extend beyond academic value, offering tangible contributions to inclusive and sustainable development planning in *IKN* buffer zones such as Balikpapan City.

CONCLUSION AND SUGGESTION

Conclusion

Based on the research results, the logistic growth model has proven effective in describing the population dynamics of the labor force and non-labor force in Balikpapan City from 2007 to 2023, with strong accuracy ($R^2 = 0.87$ and 0.88). The labor force is growing at a rate of 7.17%, higher than the 4.44% growth of the non-labor force, indicating potential improvements in future labor market conditions. The analysis also reveals fluctuations between phases of labor surplus, balance, and deficit, with a surplus peak projected in 2017, a transition to balance around 2066, and a possible deficit in the years after.

These findings highlight the importance of government intervention in anticipating future demographic trends through adaptive, inclusive, and data-driven employment policies. Although this study is limited by fixed model parameters without considering external factors such as migration, policy changes, or technology, the results offer valuable insights for sustainable human resource development in Balikpapan as a buffer zone for the Nusantara Capital City. Future studies are recommended to expand the model by including additional variables and applying

similar approaches in other regions to gain a broader perspective on workforce readiness across Indonesia.

Suggestion

Based on the study's findings, future researchers are encouraged to enhance the logistic model with more dynamic and adaptive approaches. While the Verhulst logistic model effectively illustrates labor force and non-labor force growth trends, it relies on fixed assumptions like a constant carrying capacity (K) and overlooks external factors. Future studies could explore alternative models such as Gompertz, stochastic, or machine learning-based methods to capture more complex patterns. Integrating quantitative data with qualitative insights from surveys or interviews is also recommended to better reflect the social, economic, and cultural factors influencing labor participation.

This research opens opportunities for application in other regions, particularly areas with distinct socioeconomic characteristics or those surrounding the new capital city, such as Penajam Paser Utara and Kutai Kartanegara. Tailoring models to dominant local sectors and analyzing shorter-term projections would improve their relevance for development planning. For governments and stakeholders, these findings provide a basis for proactive human resource strategies, including vocational training, education quality improvement, and job creation aligned with local potential. Strengthening collaboration between public, private, and educational sectors is essential to build a sustainable employment ecosystem, with this model serving as a tool to monitor labor market dynamics and policy effectiveness over time.

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AUTHOR CONTRIBUTIONS

VG conducted data collection and assisted and refined the writing. BTJ analyzed the data and wrote the initial draft.

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