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POPULATION MODEL WITH HEART DISEASE DEATH RATE CONSIDERATION

Nur Farwizah Roslan[1], Nur Syahirah Abdul Rahman[2] and Razihan Allias[3*]

Department of Mathematics, Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor

[1]2020483488@student.uitm.edu.my, [2]2020452594@student.uitm.edu.my, [3*]arazihan@uitm.edu.my

(indicates the corresponding author)*

ABSTRACT

Heart disease is a non-infectious disease, but it needs to be taken seriously because it takes human lives. In Malaysia, this disease is the number one highest reported disease that kills people who suffered from it. As the number of heart disease death keep increasing, prediction of Malaysia's population will be determined to examine the population towards affected disease. Malthus theory explained that population will continue expanding until growth is stopped or reversed by disease. Hence, Malthusian growth models are used to forecast Malaysia population growth. The two adjusted Malthusian model with death rate consideration is calculated by two different approaches, using fixed growth rate and fixed death rate, and using unfixed growth rate and unfixed death rate to estimate the number of populations. The Malthusian model and discrete Malthusian model are also used to calculate the estimated population without considering the death rate. The results obtained are compared and analyzed to see the differences and the accuracy. The outcome shows the efficiency of the Malthusian model in estimating the number of populations in Malaysia.

Keywords: *Death rate, growth rate, heart disease, Malthusian model.*

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1. Introduction

1.1 Background of The Study

Heart act like an engine of human body as it pumps a million barrels of blood in an average lifespan since the day we were born. It is the most important part in human body because if you have a complication of heart, other organs will be affected and have a problem too. The number of cases reported regarding heart disease in Malaysia is ever increasing day by day. A Consultant Cardiologist of Columbia Asia Hospital said that heart disease is still the number 1 killer in Malaysia (Umadevan,2022). Malaysians in their 20's and 30's are suffering from heart attacks and almost 1 in every 4 deaths is cause by heart disease. FMT Reporter (2021) also in their online newspaper aired that heart disease remains the principal cause of death in Malaysia, increasing from 11.6% of all medically certified deaths in 2000 to 17% in 2020. The number of mortality rate regarding heart disease are worrying nowadays and people need to take care of their heart carefully from now on because having a complication of heart will make your day even worse. Research done by Shafina et al. (2022) has identified the factor of cardiovascular risk among urban and rural Malaysian youths. Result gained from the investigation shows that youth in rural areas are having higher chance to get heart disease since they tend to be obese or overweight compared to urban areas. Malaysia's population might not really be affected with heart disease even though it contributes the highest death rate among Malaysian. Maybe it is because heart disease is not infectious disease, it was generally a disease that can be suffered to everyone if they are not take care of their health carefully. Therefore, mathematical modelling with heart disease rate consideration should be modelled to forecast Malaysia's population growth.

1.2 Problem Statement

One can find various type of mathematical modeling to predict population of a country, or anything related to size of inhabitants. There exists also model to study the effect and behavior of infectious disease. However, to find a model that forecast population growth with non-contagious disease is quite difficult. Maybe because this illness is not easily been spread over and the probability of people to be suffered from nontransmissible disease is less than infectious disease. Hence, research paper population model for disease that cannot be transmitted is hard to find and discover. The aim of our study is to prognosticate Malaysia's population with heart disease consideration. Therefore, a modified Malthusian model which considering death rate has been used to make an estimation population towards this country. Comparison between the modified model and real Malthusian model also will be made in order to investigate the differences between the real population and the estimated population.

1.3 Research Objective

The objective of this study is:

a) To analyze the estimated population using unfixed and fixed growth rate and death rate of heart disease.

b) To estimate population using Malthusian Model and Discrete Malthusian Growth Model without heart disease consideration.

c) To compare the differences between fixed growth rate and death rate of heart disease and Discrete Malthusian Growth Model without heart disease consideration.

1.4 Significance of Study

Malthusian Growth Model is a model that usually been used to predict number of country's population by year. A population can increase by reproduction and decrease by death. But in our study, we use Malthus's Growth Model with disease death rate consideration to estimate population of Malaysia that was affected by heart disease. A well-grounded understanding of the relation of mathematics and real-life helps us to forecast the number of populations using this model. Births and deaths depend on the current size of the population, but immigration and emigration depend on the movement of organisms in the population. The findings of this research may open people's eye on how intelligent the idea of estimating population using formula of a model with consideration of non-infectious disease that has affected citizens on a country and leads to death. People might recognize and realize the importance of mathematics in their daily lives.

1.5 Scope of Study

This study is focusing on mathematics calculation on how to estimate Malaysia population using Malthus's Growth Model with consideration of heart disease death after heart disease becoming number one killer in Malaysia. The data of Malaysia's population was obtained from legal global website, while data for death of heart disease was obtained from online news clipping, The Star. Both of the data was taken from the year 2011 until 2020.

1.6 Literature Review

1.6.1 Mathematical Modeling for Infectious Disease

There are many studies that use mathematical model to make some prediction regarding any kind of disease. Each mathematical model is used for a different function. It was designated to explain systems, study effects of components, and make predictions about behavior. Numerous examples of mathematical models to predict population with disease are found in the current study. A study done by Rahim et al. (2021) used SIR Model to predict the incidence rate of COVID-19, where they divided population into three classes which is Susceptible S(t), Infected I(t) and Recovered R(t). The results using the model shows that a high contiguous rate is contaminated from infected population to susceptible population and migration should be strictly prohibited for the sake of saving humanity. Years by years, SIR have been modified depending on the study that researcher investigated towards infectious disease. Michael et al. (2005) conducted a study about the effects of vaccination and isolation on the Severe Acute Respiratory Syndrome (SARS) epidemic and constructed the SEIRP (Susceptible-Exposed- Infective- Recovered-Persevered) model. Results from the conducted model explained that transmission of the virus or disease can be prevent if patient who are infected were isolated as soon as possible. Focusing on cellular automata model, Sheng et al. (2019) has proposed a comprehensive model known as Susceptible-Latent-Infected-Recovered-Dead-Susceptible (SLIRDS) to study the influence of the factors on the spread of infectious diseases. The outcome from the research indicates that population density contributes to the largest disease spread factor whereby the increasing population leads to the increasing of people affected towards disease. But this mathematical model not suitable to be used to predict Malaysia's population with heart disease consideration since heart disease is not consider as an infectious disease that spread easily. It was a common disease heard every year that can be suffered by various ages.

1.6.2 Malthusian Growth Model

Malthusian Growth Model is an exponential formula used to forecast population rise. It was popularized by British philosopher, Thomas Malthus in 1978. His model, although simple, has become the idea for many future modellings of biological populations (Kagan,2021). His work, "An Essay on the Principle of Population," offers an excellent examination of the limitations of mathematical modelling and should be required reading for all serious students of the subject. According to McKelvery (1995), as stated in the essay, food supply will be insufficient to keep up with population growth, resulting in sickness, starvation, conflict, and tragedy. If population growth is unregulated, it will occur in a geometric progression, but the means of sustenance will only rise in an arithmetic progression. Population will continually grow until it reaches the limit of sustenance (MacRae,2021). Harley (2021) has identified in Malthus theory, there are two sorts of 'checks' that may be used to restrict the pace of population growth. The 'positive' and 'preventive' checks that occur in the human population to prevent excessive growth are related to mortality and fertility habits, respectively. Positive checks are more effective than preventative checks in situations where positive checks are more effective, and vice versa. Malthus argued that, despite these checks, the failure of increased food supply to keep up with population growth always resulted in overpopulation. Another study done by Ashraf et al. (2008) analyze the effect of existence Malthusian population dynamics in the pre-Industrial Revolution area. The findings show that society will be naturally expand and larger in population if they are higher land productivity.

1.6.3 Research Using Malthusian Model

There is research that use Malthusian Model to predict population of a country. Nevertheless, there is also researcher been using that model for other purposes and objective of their study. Lenin et al. (2018) have done research using Malthusian model to compare with Verhulst-Pearl growth model to understand the kinetics of Photobacterium exposed to lead. Results from the study proved that Verhulst-Pearl growth model was better than the Malthusian growth model. Both researchers agree that Verhulst-Pearl growth model is the best option for proving useful and reliable information about Photobacterium kinetics growth in vitro. Increasing trend in population is a great threat to the nation and for this reason, Hironmoy et al. (2018) in their study decide to make comparison between Malthusian model and Logistic model to predict the current trends of human population growth in Bangladesh. To conclude their point of view, Logistic model gives a good forecasting result compared with Malthusian model for a long-term prediction.

Nuryaman et al. (2019) investigates the projection on the population of Bandar Lampung City in 2017 up to 2030 through a mathematical modelling approach. They use four growths mathematical models particularly simple linear regression model, Malthusian model or known as exponential model, logistic model, and demographic transition model. The smallest Mean Absolute Percentage Error (MAPE) value between the models was chosen to approximate the population. Results of the analysis shows that Malthusian model has the smallest MAPE and suitable to be used to forecast population growth in the future, while largest MAPE is demographic transition model.

2. Methodology

2.1 Thomas R. Malthus

The research methodology to achieve the objectives of this study is described as follows:

Thomas R. Malthus, an Englishman, created a mathematical model of population growth in 1798.

$$\begin{cases} \frac{dP}{dt} = \lambda P, \lambda > 0 \\ P(t_0) = P_0 > 0 \end{cases} \qquad (2.1.1)$$

where λ in equation $\frac{dP}{dt} = \lambda P,$ expresses population growth rate and it reflects a strong impact

on how fast the population will grow. $\frac{dP}{dt} = \lambda P,$ indicates $\frac{dP}{dt}$ increases to infinity as t increases, implying that the model population grows to infinity as due to the increase to infinity.

$P(t_0) = P_0 > 0$ expresses the population size when $t = t_0$.

Malthus's model voices such principles:

1. Man must eat to survive.
2. Rate of population growth is higher than of food production rate.
3. Consequences of these rates need to be kept equal.
4. Decrease in population is due to famine, disease, poverty and war.

Based on equation $\frac{dP}{dt} = \lambda P$, it is obtained that

$$P^{-1}dP = \lambda dt$$

$$\int_{t_0}^{t} P^{-1}dP = \int_{t_0}^{t} \lambda dt \qquad \text{(integrating for both sides)}$$

$$\int_{t_0}^{t} \frac{1}{P}dP = \int_{t_0}^{t} \lambda dt$$

$$\ln P \mid_{t_0}^{t} = \lambda \mid_{t_0}^{t} \qquad (2.1.2)$$

$$\ln t - ln\, t_0 = \lambda t - \lambda t_0 \qquad (2.1.3)$$

$$\ln\left(\frac{t}{t_0}\right) = \lambda(t - t_0) \qquad (2.1.4)$$

$$e^{\ln\left(\frac{t}{t_0}\right)} = e^{\lambda(t-t_0)} \qquad (2.1.5)$$

$$\left(\frac{t}{t_0}\right) = e^{\lambda(t-t_0)} \qquad (2.1.6)$$

$$\left(\frac{P}{P_0}\right) = e^{\lambda t}.e^{-\lambda t_0}$$

$$P = (P_0.e^{-\lambda t_0})e^{\lambda t} \qquad (2.1.7)$$

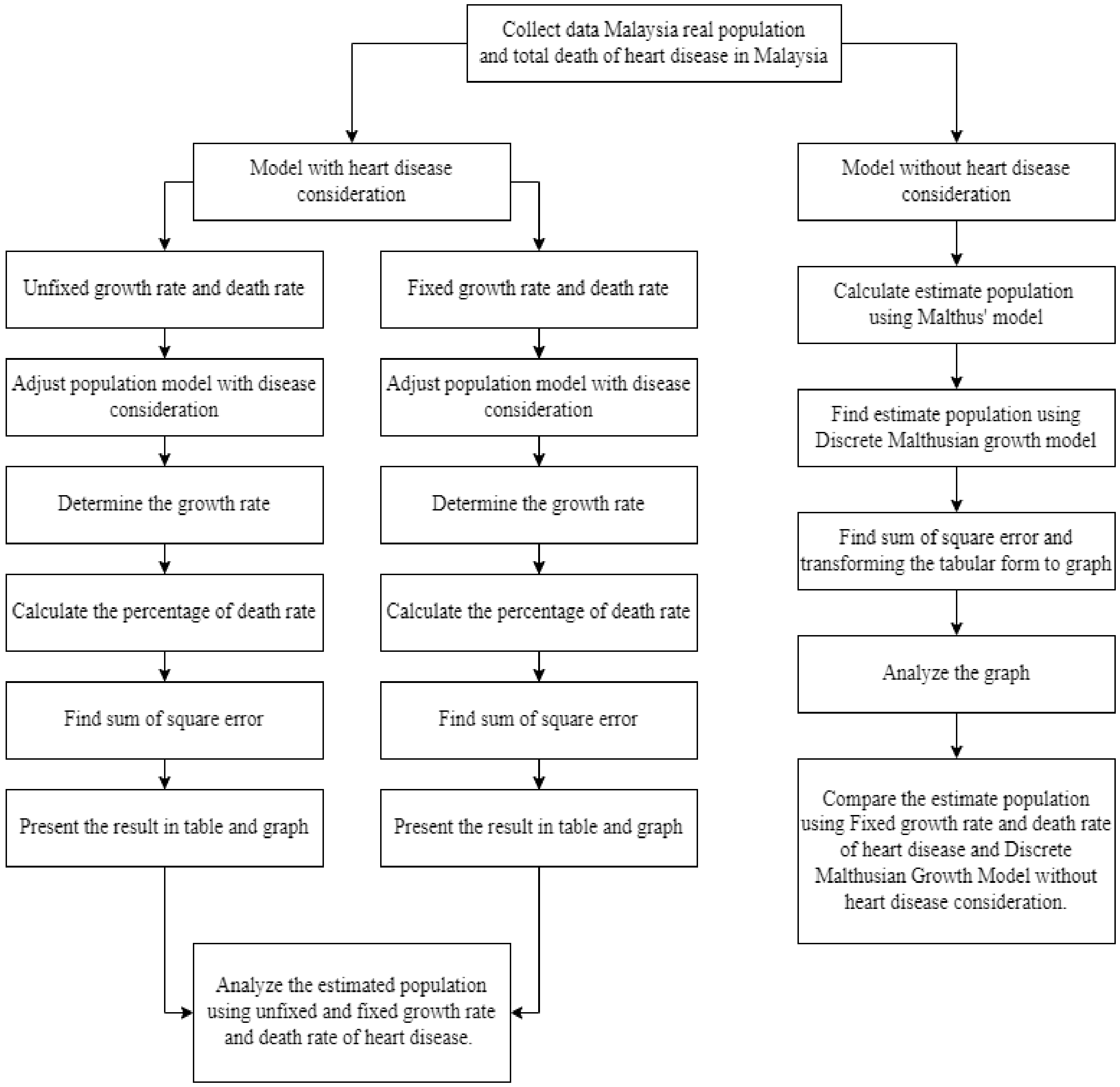
$$P = ce^{\lambda t} \qquad (2.1.8)$$

Thus

$$P = \left(P_0 e^{-\lambda t_0}\right)e^{\lambda t} = ce^{\lambda t}$$

where $c = P_0 e^{-\lambda t_0}$ is a constant for some fixed λ. The resolution $P = ce^{\lambda t}$ (2.1.8) clearly indicates P is an exponential of e. Its physical meaning expresses that population sizes grow exponentially as time t.

2.2 Flow Chart



2.3 Model with Heart Disease Consideration

Model with heart disease is used to estimate Malaysia's population using two approaches which is considering fixed growth rate and death rate, and also by using unfixed growth rate and death rate.

i) Using unfixed growth rate and death rate

STEP 1: Obtained data of Malaysia's population from the year 2010 to 2020

STEP 2: The adjusted population model with disease consideration

$$P = P_0 e^{\lambda t} - (b \times P_0)$$

$$P = P_0(e^{\lambda t} - b) \tag{2.3.1}$$

where P is the number of populations at time,t (years)

P_0 is the number of initial populations,

λ is the growth rate,

b is the percentage of death rate induced by heart disease

STEP 3: Find the growth rate and death rate

a) The growth rate will be determined by using this formula:

$$\text{Growth rate}, \lambda = \frac{P_{n+1} - P_n}{P_n} \tag{2.3.2}$$

where n is the number of years,

P_n is the population of n years,

P_{n+1} is the population of next year

b) Percentage of death rate, *b* will be calculated by using this formula:

$$\text{Percentage death rate}, b = \frac{\text{Total death}}{(\text{Total population} + \text{total death})} \times 100 \tag{2.3.3}$$

STEP 4: Find sum of square error

STEP 5: Results calculations are presented in table and graphs

ii) Using fixed growth rate and death rate

STEP 1: Obtained data of Malaysia's population from the year 2010 to 2020

STEP 2: The adjusted population model with disease consideration

$$P = P_0 e^{\lambda t} - (b \times P_0)$$

$$P = P_0 (e^{\lambda t} - b)$$

where P is the number of populations at time, t (years)
P_0 is the number of initial populations,
λ is the growth rate,
b is the percentage of death rate induced by heart disease

STEP 3: Find the growth rate and death rate

c) - The growth rate will be determined by using this formula:

$$\text{Growth rate}, \lambda = \frac{P_{n+1} - P_n}{P_n}$$

where n is the number of years,

P_n is the population of n years,

P_{n+1} is the population of next year

- Average growth rate of n years will be calculated

d) Percentage of death rate, *b* will be calculated by using this formula:

$$\text{Percentage death rate}, b = \frac{\text{Total death}}{(\text{Total population} + \text{total death})} \times 100$$

We will use P_0 of total death rate to calculate percentage death rate

STEP 4: Find the sum of square error

STEP 5: Results calculations are presented in table and graphs

STEP 6: Analyze the estimated population using unfixed and fixed growth rate and death rate of heart disease.

2.4 Model Without Heart Disease Consideration

Model without heart disease consideration is used to estimate the Malaysia's population using two types of models which are Malthus's Model and Discrete Malthusian Growth Model

STEP 1: Estimated population using Malthus' Model

Population without disease can be determined using this formula:

$$P = \left(P_0 e^{-\lambda t_0}\right) e^{\lambda t} = c e^{\lambda t}$$

where λ is a growth rate, and $c = P_0 e^{-\lambda t_0}$ is a constant for some fixed λ. The resolution $P = ce^{\lambda t}$ clearly indicates P is an exponential of e. Its physical meaning expresses that population sizes grow exponentially as time t.

STEP 2: Estimated population using Discrete Malthusian Growth Model

Population without disease can be determined using this formula:

$$P_{n+1} = (1 + \lambda)^n P_0 \qquad (2.4.1)$$

where n is number of years, and λ is average of growth rate

STEP 3: Find sum of square error and transforming the tabular form to graph Sum of square error will be calculated to find the smallest error.

STEP 4: Analyze the graph

The graphical results will be discussed, and the analysis will focus on comparing between Malthus's model and Discrete Malthusian growth model.

STEP 5: Compare the estimated population using Fixed growth rate and death rate of heart disease and Discrete Malthusian Growth Model without heart disease consideration.

3. Results and Discussion

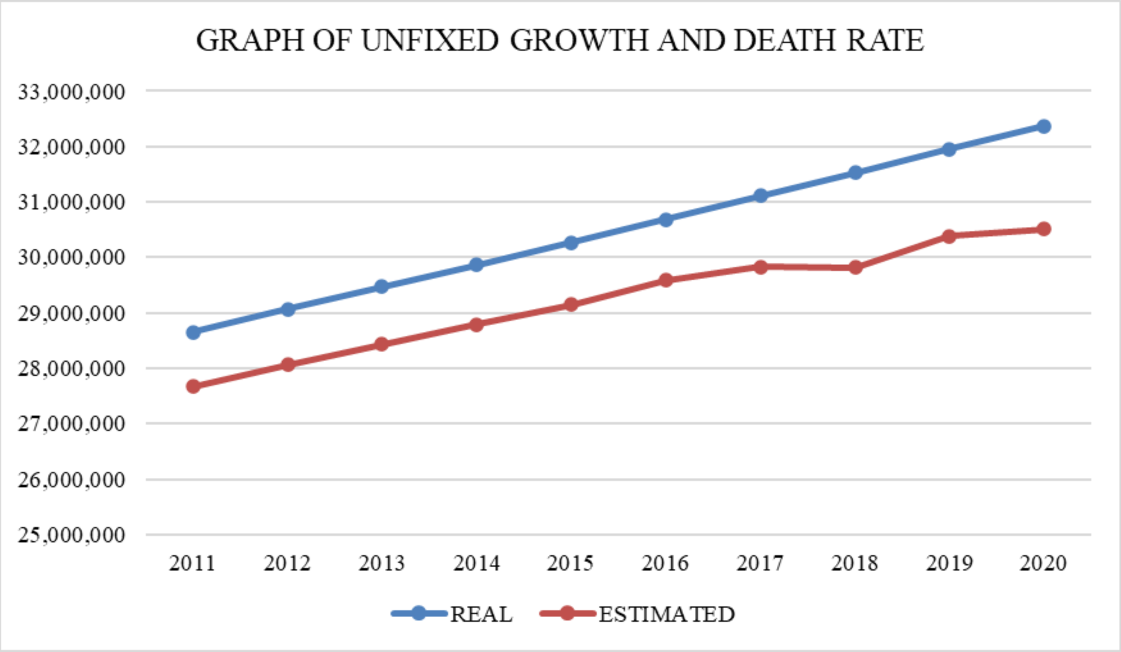


Figure 3.1: Real and estimated population using unfixed growth and death rate

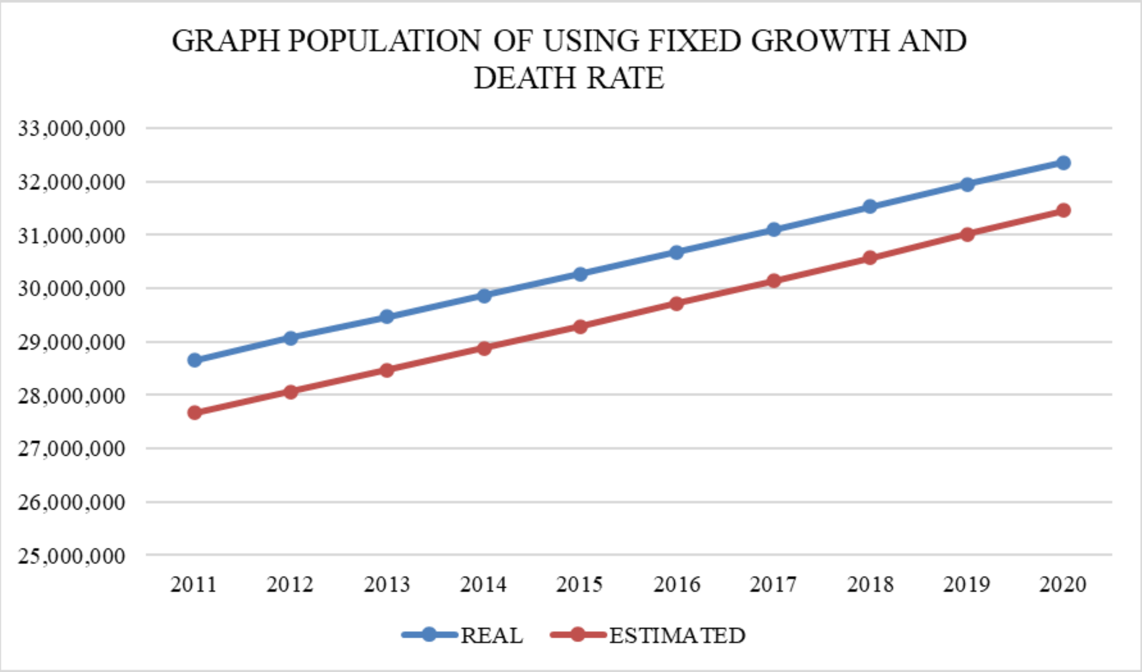


Figure 3.2: Real and estimated population of fixed growth and death rate

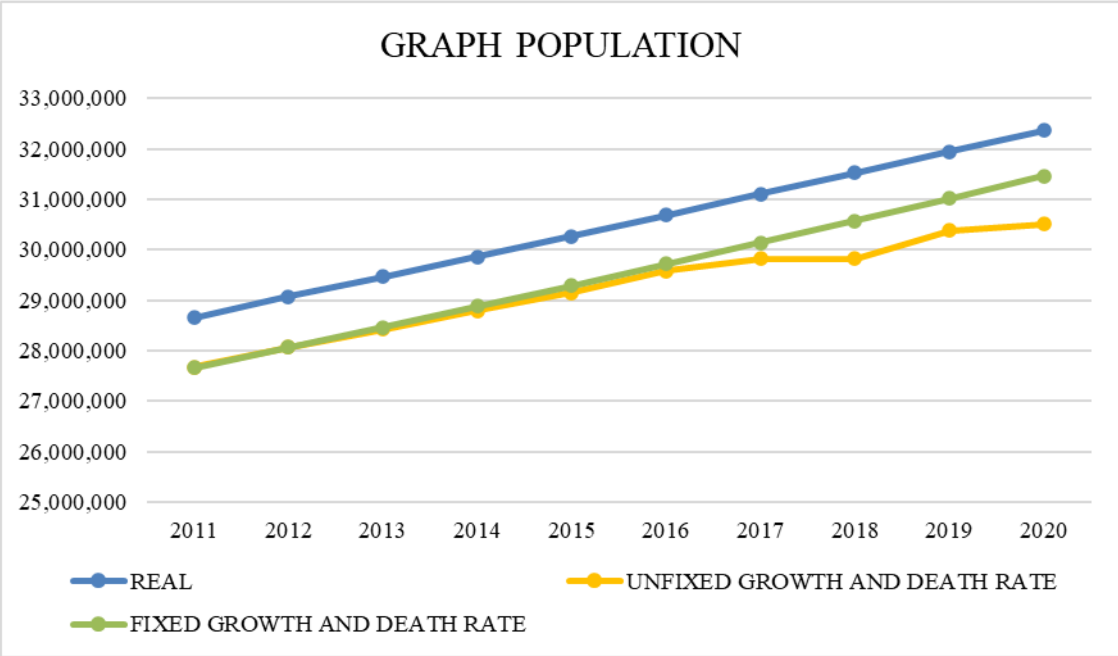


Figure 3.3: Real and estimated population with heart disease consideration

Table 3.1: Estimated population and Real population of Fixed Growth and Death Rate

YEAR	**ESTIMATED POPULATION, x**	**REAL POPULATION, y**	$x - y$	$(x - y)^2$
2010	-	28,208,035	-	-
2011	27,664,646	28,650,959	986,313	9.728×10^{11}
2012	28,063,532	29,068,189	1,004,657	1.009×10^{12}
2013	28,467,980	29,468,923	1,000,943	1.002×10^{12}
2014	28,878,070	29,866,603	988,533	9.772×10^{11}
2015	29,293,878	30,270,962	977,084	9.547×10^{11}
2016	29,715,486	30,684,654	969,168	9.393×10^{11}
2017	30,142,974	31,104,646	961,672	9.248×10^{11}
2018	30,576,423	31,528,033	951,610	9.056×10^{11}
2019	31,015,917	31,949,777	933,860	8.721×10^{11}

2020	31,461,541	32,365,999	904,458	8.180×10^{11}
TOTAL				$\mathbf{9.376\times 10^{12}}$

$$\text{Mean Square Error} = \frac{9.376\times10^{12}}{10}$$

$$= 9.376 \times 10^{11}$$

$$\text{Standard Error} = \sqrt{9.376 \times 10^{11}}$$

$$= 968{,}297.475$$

$$\approx 968{,}298$$

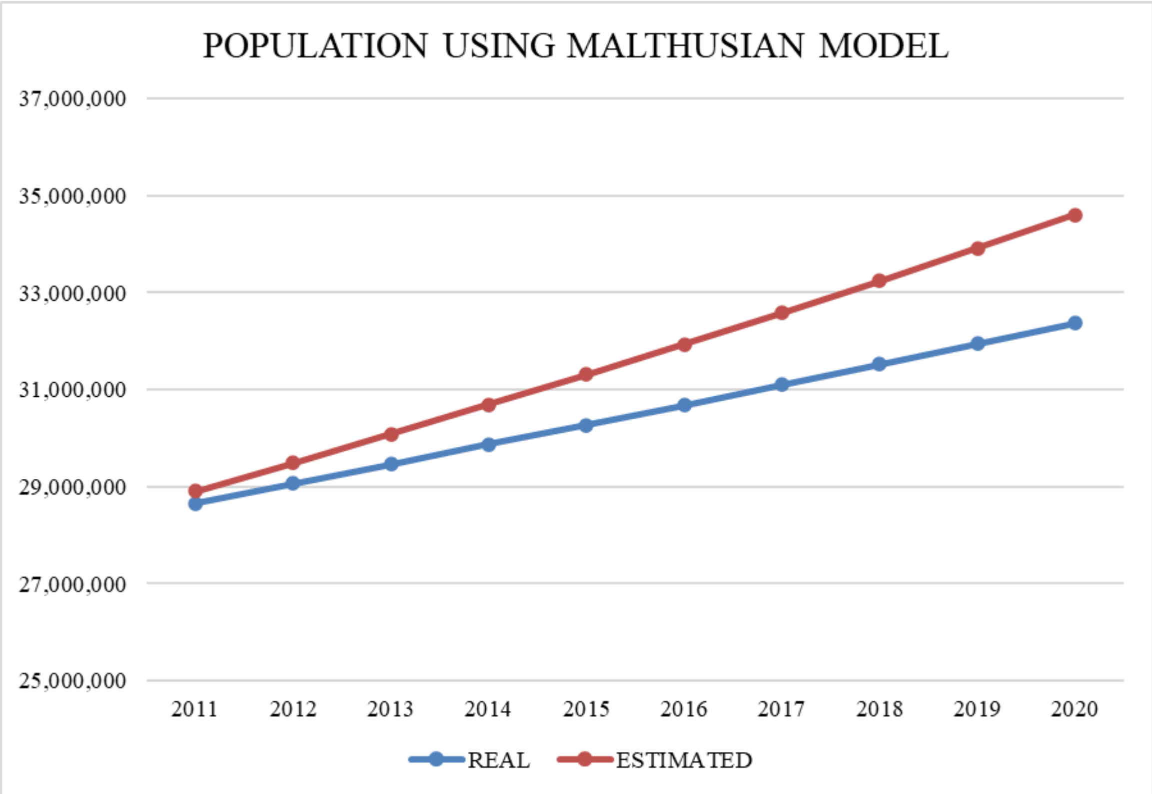


Figure 3.4: Malaysia's population using Malthusian Model

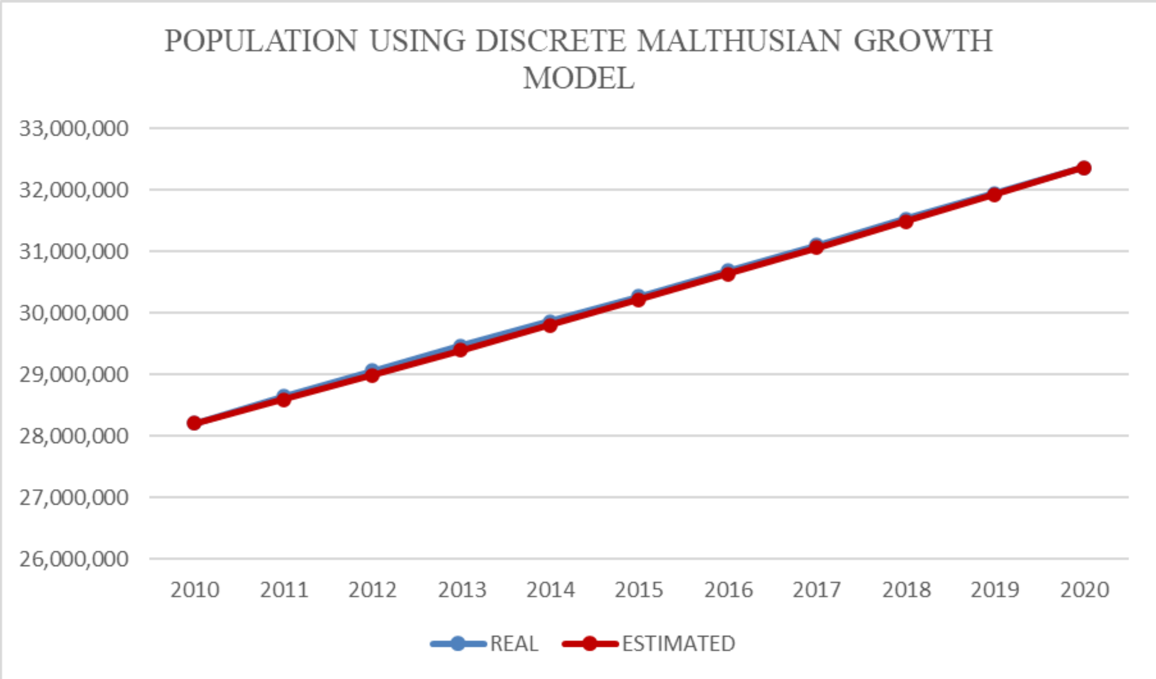


Figure 3.5: Malaysia's population using Discrete Malthusian Growth Model

Table 3.2: Estimated population using Discrete Malthusian Growth Model

n	YEAR	ESTIMATED POPULATION, x	REAL POPULATION, y	$x-y$	$(x-y)^2$
0	2010	28,208,035	28,208,035	0	6.29×10^9
1	2011	28,598,717	28,650,959	52242	2.73×10^9
2	2012	28,994,809	29,068,189	73380	5.38×10^9
3	2013	29,396,387	29,468,923	72536	5.26×10^9
4	2014	29,803,527	29,866,603	63076	3.98×10^9
5	2015	30,216,306	30,270,962	54656	2.99×10^9
6	2016	30,634,802	30,684,654	49852	2.49×10^9
7	2017	31,059,094	31,104,646	45552	2.07×10^9

8	2018	31,489,262	31,528,033	38771	1.50×10^9
9	2019	31,925,388	31,949,777	24389	5.95×10^8
10	2020	32,367,555	32,365,999	-1556	2.42×10^6
TOTAL					$\mathbf{2.70\times 10^{10}}$

$$\text{Mean Square Error} = \frac{2.70\times10^{10}}{10}$$

$$= 2.70\times 10^9$$

$$\text{Standard Error} = \sqrt{2.70\times 10^9}$$

$$= 51{,}961.52$$

$$\approx 51{,}962$$

4. Conclusion and Recommendations

In this study, we separate the implementation into two parts, which are Malthusian growth model with disease consideration and the Malthusian growth model without disease consideration. The discrete Malthusian model is also used to estimate the Malaysia population without considering the heart disease.

Under the death consideration, we analysed the results obtained by comparing the estimated population between the approaches using unfixed and fixed growth and death rates. Firstly, we can see from Figure 3.1 and Figure 3.2 that for both approaches, unfixed and fixed growth and death rate, the number of populations decreases every year due to the number of deaths, and the number of estimated populations grows linearly (quite exponentially) as the real population. In 2018 to 2020, there were fluctuations because the number of deaths in 2018 increased dramatically to 18,267 from 13,503 in 2017. The hypothesis for this graph is that the higher the number of deaths, the lower the growth rate. If we compare the results between unfixed and fixed growth and death rates as shown in Figure 3.3, the estimated number of populations using fixed growth and death rates gives a better result since the estimated population is almost closer to the real number of populations. The lowest sum square error that obtained from Table 3.1 indicates the best ability of the model to accurately predict the data. But somehow, by using the unfixed growth and death rate, it follows the nature of drastic increases number of deaths in 2018 that fluctuates.

Now considering the result for the Malthusian growth model without disease for Malaysia, Figure 3.4 shows that the population size begins to differ even more as the time increases compared to the actual population. Whereas, the discrete Malthusian growth model is well matched compared to the real population of Malaysia, as shown in Figure 3.5. Thus, the discrete Malthusian growth model is more suitable to approximate the future population as the years increase since it gives lowest sum square error compare to Malthusian model.

The comparison the estimate population using Fixed growth rate and death rate of heart disease and Discrete Malthusian Growth Model without heart disease consideration, we can see the estimated population without disease is more accurate to the actual population. As we know, death is not only caused by heart disease, it can also be caused by accidents, other diseases, murder, and so on. But in our study, we only used data on the number of deaths from heart disease. We chose death from heart disease because heart disease is the highest cause of death in Malaysia. The prediction of the population size without considering diseases is best suited to actual populations because the number of deaths is not just due to heart disease.

Based on the equation (2.4.1), we can estimate the population of Malaysia in the future, for example, from 2021 to 2030.

Table 4.0: Estimated Malaysia's population for 10 years

n	**Year**	**Estimated Population** $P_{n+1} = (1.01385)^n(28{,}208{,}035)$
11	2021	32,815,846
12	2022	33,270,345
13	2023	33,731,139
14	2024	34,198,316
15	2025	34,671,962
16	2026	35,152,169
17	2027	35,639,027
18	2028	36,132,627
19	2029	36,633,064
20	2030	37,140,431

The estimation population of Malaysia in 2030 is 37,140,431.

Malthusian Growth Model is a model that usually been used to predict number of country's population by year. A population can increase by reproduction and decrease by death. But in our study, we use Malthus's Growth Model with Disease Death Rate Consideration to estimate population of Malaysia that was affected by heart disease. A well-grounded understanding of the relation of mathematics and real-life helps us to forecast the number of populations using this model. Births and deaths depend on the current size of the population, but immigration and emigration depend on the movement of organisms in the population. The findings of this research may open people's eye on how intelligent the idea of estimating population using formula of a model with consideration of heart disease that has affected citizens on a country and leads to death. People might recognize and realize the importance of mathematics in their daily lives.

What effect does this have on population growth, and how does it affect the calculation? So this project is to show a more realistic population prediction model that would be able to factor in certain changes in reality and certain changes in our environment that would cause disease death and how that affects our prediction that affects the real population and thus, at the end of the day, we will check and calculate and compare the population prediction numbers and the actual data. The environment in which we will be testing this on Malaysia.

According to our findings, the discrete Malthusian growth model is ideally suited compared to the real population of Malaysia. This Discrete Malthusian Growth Model is appropriate to approximate the future population as the years increase. Additionally, fixed growth and death rate that is more similar to the actual population. As a result, fixed growth and death rate is best suited to use in the Malthusian Growth Model with disease.

For further recommendation, we can use Malthusian or discrete Malthusian model by considering other diseases. More parameters can be used to get better prediction and if possible, to get data on a monthly basis as we can choose infected disease like COVID-19.

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