Model of relationship between car ownership growth and economic growth in Java

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Abstract. Vehicle growth is a problem that is inseparable from sustainable transportation. In 2014, the number of private vehicle ownership in Indonesia reached more than 448 vehicles per 1,000 people. Specifically, for cars it reaches 324 vehicles per 1000 people. The growth of private vehicle ownership is strongly influenced by economic growth (one measure of the economic growth of the economy is Gross Domestic Product - GDP). It is necessary to look at the mathematical relationship between trends in economic growth represented by GDP and the growth of private vehicle ownership, with a model. This research is located on Java Island using provincial administrative based data (5 provinces namely Banten, Capital Region of Jakarta, West Java, Central Java, and East Java). The growth model of vehicle ownership on Java, in general, can be approached with the Gompertz Function. The Gompertz function is a type of mathematical model for a time series and is named after Benjamin Gompertz (1779-1865). It is a sigmoid function which describes growth as being slowed at the start and end of a given time period.

1. Introduction
Many developing countries have experienced high growth in motorized vehicles at the end of this decade, along with the development of their economic growth [1]. The results of the study on the sustainable mobility project (World Business Council for Sustainable Development, 2004) projected a five-fold increase in the number of vehicles in China and Latin America in 2050. Meanwhile, in Indonesia, the 2014 Central Bureau of Statistics noted that the number of motor vehicles had reached 114,209,266 units consisting of 12,599,138 passenger cars, 2,398,846 buses, 6,235,136 freight cars, and 92,976,240 motorbikes. The increase in the number of motorized vehicles per year in Indonesia is 14.55%, this increase is a very high increase compared to the increase in the average population in the range of 2010-2016 which is equal to 1.36%. If the population of Indonesia in 2014 was 254.9 million (Susenas 2014), the choice of motorized vehicles in Indonesia reached more than 448 vehicles per 1,000 people. The number and growth of these vehicles is a separate problem related to sustainable transportation.

Increased ownership of motorized vehicles will certainly also affect economic growth. Economic growth in Indonesia, between the period 2000-2004, economic recovery occurred with an average growth of Gross Domestic Product (GDP) at 4.6% per year [2]. After that, GDP growth accelerated (with the exception of 2009 time, due to global financial shocks and uncertainty, Indonesia's GDP growth fell to 4.6%, a figure that is still amazing) and peaked at 6.5% in 2011. Nevertheless, after 2011...
the expansion of the Indonesian economy began to slow down greatly. Between 2011 and 2015 Indonesia's economic growth slowed sharply (which is explained in more detail below). When compared with the growth of motorized vehicles, it can be concluded while the growth rate of high motor vehicles at the end of this decade actually has an impact on declining GDP.

By taking into account the background of the very rapid development of motorized vehicles and the possible impacts that arise as a result, it is necessary to examine the extent of the influence of ownership of motorized vehicles (especially cars) on the economic growth of a region or vice versa. Several previous studies have tried to build a model to predict the growth of motorized vehicles, which of course the results can be used as a reference for planning. The growth of motorized vehicles from various countries, especially developing countries, was concluded following the S-Curve pattern [3]. A study of several growth models of motorized vehicles related to socio-economic independent variables and other variables such as vehicle type, demand-supply, and others has also been done [4]. In Columbia, a model has been created to predict the increase in ownership of motorized vehicles (motorbikes and cars), and has tested the sensitivity of income levels to the ownership of these vehicles [5]. Based on the per capita GDP of the population, the growth of vehicles in China follows the S-Curve pattern [6]. From a number of studies submitted it can be said that there is a significant relationship between the growth of vehicles with socio-economic variables, especially GDP (income).

Given the importance of predicting the growth of motorized vehicles, this paper will discuss the relationship between the growth of motor vehicles and economic progress with the main indicator of GDP per capita. In the discussion, this paper takes a case study on Java and the type of vehicle to be studied is a car because this type of vehicle has a fairly high growth rate.

2. Methodology

2.1. Gompertz Model for Vehicle Ownership Predictions
The speed of expansion of vehicle ownership in developing countries is mainly driven by market demand, this means that an increase in vehicle ownership is closely related to the level of consumer wealth and intention to buy [6]. Income variables usually better reflect aggregate demand. Therefore, researchers can use per capita income as an economic factor in Gompertz's functions in developing countries. The Gompertz function is widely applied to build relationships between motor vehicle ownership and economic factors. The relationship of increasing motor vehicle ownership per 1,000 people was approached by the Gompertz Model as in equation 1.

\[ V_t^* = \gamma \cdot e^{\alpha \cdot e^{\beta \cdot GDP_t}} \]

where
\[ V_t \quad : \quad \text{vehicle ownership per 1000 people in year t model} \]
\[ GDP_t \quad : \quad \text{Per capita GDP in year t} \]
\[ \gamma \quad : \quad \text{coefficient which describes the saturation condition of vehicle ownership per 1,000 residents} \]
\[ \text{this figure is taken as the maximum value of vehicle ownership data per 1,000 residents, which is 1,299 vehicles / 1,000 people} \]
\[ \alpha \quad : \quad \text{negative coefficient which describes the initial condition of the model} \]
\[ \beta \quad : \quad \text{negative coefficient which determines the curvature of the Gompertz curve} \]

In general, the Gompertz model will form an S-Curve pattern, as in Figure 1a.
2.2. Gompertz Model Sensitivity

The sensitivity of the model uses internal equations [3], as follow:

\[ \mu_t^{LR} = \alpha \cdot \gamma \cdot GDP_t \cdot e^{\beta \cdot GDP_t} \]  

(2)

This elasticity is all positive at all GDP levels because \( \alpha \) and \( \beta \) are negative. The elasticity value increases from GDP = 0 to maximum at GDP = -1 / \( \beta \) then decreases to zero asymptote line (as in Figure 5b).

3. Discussion

3.1. Growth of Motor Vehicles, Population and Road Network in Indonesia

The number of motorized vehicles in Indonesia in 2015 reached 121.39 million units [7]. Data from the Central Statistics Agency (BPS) shows that of these figures the most were motorbikes with 98.88 million units (81.5 percent). Passenger cars followed with a total of 13.48 million units (11.11%), then freight cars 6.6 million units (5.45%), and bus cars with 2.4 million units (1.99%) of the total vehicle. While this data was collected from BPS Indonesia, the growth of motorized vehicles (passenger cars and motorbikes) from 1949-2015 can be seen in Figure 2.

Figure 2. Growth in the number of motorized vehicles (passenger cars and motorbikes) in Indonesia
The annual growth rate of motor vehicles from 1949-2014 was 11.96% / year for passenger car vehicles and 19.59% / year for motorcycle vehicles. The growth of these vehicles also far exceeds the growth of Indonesia's own population which in the range of 2010-2016 was 1.36%.

Furthermore, what needs to be considered related to the growth of motorized vehicles is supporting infrastructure for motorized vehicles, namely in the form of road networks. Data on paved road networks in Indonesia from 1957-2016 can be seen in Figure 3. The average development per year is 6%. This will be a big problem if the rate of increase is far below the growth of motor vehicles. Impacts that occur such as congestion, pollution, etc. will be more quickly achieved. Another derivative impact is that economic conditions will get worse because, for example, the cost of travel is higher due to congestion, health costs due to pollution, stress costs due to road conditions, and other costs.

![Figure 3. Development of the length of paved roads in Indonesia](image)

### 3.2. *Indonesia's Gross Domestic Product (GDP) as an Indicator of Economic Progress*

In the economy of a country there is an indicator that is used to assess whether the economy is going well or badly. Indicators in assessing the economy must be used to find out the total income earned by everyone in the economy. The right and appropriate indicator in making these measurements is the Gross Domestic Product (GDP) / Gross Domestic Product (GDP). And GDP per capita which is the amount of GDP when compared to the population in a country is a better tool that can tell us what happens to the average population, the standard of living of its citizens.

### 3.3. *Relationship Between Vehicle Growth and Economy*

Referring to several previous studies, that there is a very strong relationship between economic growth (with GDP indicators) and vehicle ownership per 1000 population [6]. In the Java research location Banten Province, DKI Jakarta Province, West Java Province, Central Java Province and East Java Province, the relationship between vehicle ownership and Per capita GDP is shown in Figure 4. There is a very significant relationship between the two variables.
Figure 4. Relationship between motor vehicle ownership and annual GDP in several provinces in Java

3.4. Calibration Results of the Relationship Model of Car Ownership with GDP of Per capita in Java Island

Furthermore, the Gompertz Model was applied in the Car Growth Model for case studies in Java using data from 5 provinces, namely the Special Capital Region (DKI) of Jakarta, Banten Province, West Java Province (West Java), Central Java Province, and Java Province. East (East Java). The data used is socio-economic data in the form of GDP per capita data and vehicle ownership data from 2005 to 2014.

Based on the Gompertz model, the initial value of the $\alpha$ coefficient describes the initial condition calculated using the formulation approach used by [9]. If in year $t = 1$, the GDP value is 0 and $V^*_1 = 1$ then equation (1) will be $1$

$$V^*_1 = \gamma \cdot e^{\alpha e^{B\alpha}}$$

$$V^*_1 = \gamma \cdot e^{\alpha}$$

So,

$$\alpha = \log \frac{\gamma}{V^*_1} \rightarrow \alpha = \log \frac{324}{1} = 5.021$$
\( \gamma \), coefficient which describes the saturation condition of vehicle ownership per 1000 residents (this figure is taken as the maximum value of vehicle ownership data per 1000 inhabitants, namely 324 vehicles / 1000 people). So that there is only a coefficient perlu that needs to be calibrated. With a simple calibration model (R2), with various applications of the value of \( \beta \), the best value of \( \beta \) is 0.0325 with an R2 value of 0.9456. The result of the calibration coefficient iteration \( \beta \) can be seen in Figure 5.

![Figure 5. \( \beta \) coefficient calibration results](image)

Plotting existing data compared to the model can be seen in Figure 6. The growth model of cars based on GDP obtained is:

\[
V^*_1 = 1299.\ e^{3.11361.\ e^{0.023.\ GDP_t}}
\]  

(6)

![Figure 6. Comparison of model results with existing data](image)
It is seen that the growth pattern of the car follows the pattern of the Gompertz model with asymptotes in 324 cars per 1,000 inhabitants. The province with the highest level of ownership is DKI Jakarta Province, while the other provinces are at the beginning of the increase in function. The provinces of Central Java and East Java have growth rates above the S-Curve Gompertz while West Java and Banten are at the bottom of the curve.

The results of the model sensitivity were obtained that the highest peak sensitivity was at 30 million GDP/year with a sensitivity value of 1.8465. The results of total sensitivity can be seen in Figure 7.

![Figure 7. Sensitivity of car ownership to GDP](image)

4. Result
The car growth model on Java Island can be approached with the Gompertz function. This function is a negative exponential function with the asymptote used is the highest value of ownership of four-wheeled vehicles in the DKI Jakarta Province, namely 324 four-wheeled vehicles per 1,000 residents. If all provinces are assumed to follow the Gompertz pattern, it can be estimated that at one time per 1,000 people there will be 324 cars, meaning the number of four-wheeled vehicles will range from 32.4% to the total population.

5. Suggestions for Advanced Research
The Gompertz function for predicting motorized vehicle ownership can be applied to other regions by recalibrating its forming coefficients. Further research is also needed regarding the value of vehicle ownership asymptotes in each region and also needs to be developed with other economic variables.
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