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Car Ownership Modeling in Aceh Province Using a Spatial Regression Approach

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Abstract
The rise in car ownership in Aceh Province has been driven by population growth and economic development. The location of the owner's residence impacts vehicle ownership. There are common spatial dependencies in this area, meaning the significance of an observation in one area is influenced by its importance in another. Factors such as population, regional income, wages and salaries, area size, and road length are believed to impact vehicle ownership. This study aimed to determine the variables affecting vehicle ownership in Aceh Province. Spatial regression analysis was used to identify the determinants of vehicle ownership in Aceh Province. Secondary data was obtained from the Aceh Province One-Stop Administration System Office (SAMSAT) for vehicle ownership documentation, the Aceh Province Wealth and Income Service for vehicle ownership recap data, and other sources such as the Central Bureau of Statistics of Aceh Province for information on population, regional income, wages/salaries, area, road length, and ages. The results showed that car ownership is dependent on geography. The Spatial Error Model (SEM) with an Akaike Info Criterion (AIC) value of 107,919 was found to be the best spatial regression model. Population (X1), regional income (X2), road length (X5), and age over 17 (X6) were found to be the parameters with a significant level of 5% that impact vehicle ownership in Aceh Province

Introduction

The increase in population accompanied by economic growth in the Province of Aceh has increased the ownership of motorcycles and private cars from year to year. Both modes of transportation have different capacities that certainly have a significant impact on land transportation. The use of motor vehicles is already widespread not only due to the growth of the population accompanied by an improvement in public welfare but also accompanied by an increase in the activities of the population covering economic, social-cultural, and political fields, the extent of activity in each field, the limited access to public transportation, and the number of public transportation available.

Transportation must provide maximum benefits to the community by minimizing time and cost. If the level of public transportation service is low, then the public's interest in using private vehicles is much higher. Besides the low level of public transportation service, many private transportation producers, especially motorcycles and private

cars, provide intensive promotions to increase sales, such as bonuses, low credit interest, and extended credit periods, making the community tempted to own private vehicles.

Moreover, public transportation is considered no longer effective and efficient compared to private transportation, such as the number of transfers required to reach the destination, the unpredictable frequency and waiting time for public transportation, and the considerable distance for potential passengers to reach public transportation. This condition will ultimately drive potential public transportation users to use private transportation in their movements. This then leads to an increase in private transportation movements and causes various urban transportation problems, such as the accumulation of transportation modes on city road networks, air pollution, traffic accidents, and other transportation problems(Kawengian, Jansen, & Rompis, 2017). Therefore, the government must implement policies limiting private vehicles and promoting reliable public transportation facilities.

Based on the above discussion, a spatial approach method was utilized to understand the complexity of the transportation system. This method allows the visualization of vehicle ownership and its influencing variables to provide easy-to-understand information and analysis, especially in terms of comparison(Susantono, Santosa, & Budiyono, 2011). The variables used in this study were the population size, the regional income, the number of wages/salaries of workers, the area size, the length of roads, and the people over 17 years old. This study aimed to determine the relationship between the increase in private car ownership in each district/city in the Province of Aceh and its influencing factors by using the aforementioned variables through spatial analysis. The ownership of private cars is of great importance in the transportation system and is closely related to land-use planning.

Materials and Methods

The research variables consisted of independent variables (X) and dependent variable (Y). Independent variables included population (X1) in terms of the number of people, regional income (X2) in terms of millions of rupiah, wage amount (X3) in terms of rupiah, land area (X4) in terms of area, road length (X5) in terms of kilometers, and people over 17 years old (X6) in terms of the number of people. The dependent variable was the ownership of vehicles (Y) in terms of units.

Data analysis techniques can be described as follows:

1. Data Preparation
   The data preparation process was performed using Microsoft Excel software. The first step was to select data in each regency/municipality based on the variables used in the research. The total data obtained was 7, consisting of 1 dependent variable and 6 independent variables. Furthermore, the data were combined into one sheet. The districts/cities were alphabetically sorted so that it was equal to the district/city in the attribute table in the Arc-GIS software.
2. Descriptive analysis
   The descriptive analysis was carried out to explore the data to get a general picture of the data used. The data exploration in this research was done by looking at the thematic map and summary statistics. The thematic map was used to understand the pattern of vehicle ownership distribution in the Province of Aceh using the quantile value in classifying the data distribution where the variable value is divided into four categories based on its value interval, and summary statistics were used to look at the data distribution description.
3. Inferential analysis
   Inferential analysis was performed through Pearson correlation and spatial regression analysis(Yuriantari, Hayati, & Wahyuningsih, 2017). The steps are as follows:
   a. Performing a Pearson correlation analysis
      Pearson's correlation coefficient analysis was used to determine the independent variables that had a significant relationship with the dependent variable. If the p-value $<\alpha$, then the variable is used in the formation of the model.
   b. Forming a spatial weighting matrix

The formation of the spatial weight matrix in this research used the queen contiguity type. The spatial weight matrix with the queen contiguity type was suitable for use in regions with an asymmetrical shape, such as the Province of Aceh. The first step was determining the number of closest neighbors (k) for the optimal spatial weight matrix for each district/city. The determination of the k value was seen from Moran's I statistic, which was done iteratively. The value of Moran's I was chosen based on the largest value produced. After the k value had been determined, the spatial weight matrix could be formed.

c. Performing a spatial autocorrelation test
   1) Global Moran Index
      The global spatial autocorrelation test examined the spatial relationship among the districts/cities in the Province of Aceh. The hypothesis used for the spatial autocorrelation test with the Global Moran's Index is as follows:
      a) H0: I = 0 (there is no global spatial autocorrelation among the regencies /municipalities in the Province of Aceh).
      b) H1: I ≠ 0 (there is global spatial autocorrelation among the regencies /municipalities in the Province of Aceh).
   2) Local Moran Index
      The test of local spatial autocorrelation was performed to examine the spatial relationship in each regency/city in the Province of Aceh that was truly affected by its neighboring regions. The hypothesis used for the test of local spatial autocorrelation with the local Moran index is as follows:
      a) H0: Ii = 0 (there is no local spatial autocorrelation in the i-th regency/municipality in the Province of Aceh).
      b) H1: Ii ≠ 0 (there is local spatial autocorrelation in the i-th regency/municipality in the Province of Aceh).

      The rejection criteria for decision-making in the global and local Moran index tests are to reject H0 if the value of $Z(I) > Z(\alpha/2)$ or p-value < α.
   3) Moran Scatter Plot
      The local Moran index test results were visualized in the form of a Moran scatterplot. In the visualization, the x-axis represented the prevalence of motor vehicle ownership, and the y-axis represented the standardized average number of motor vehicle ownership in the i-th regency/municipality.
d. Interpreting spatial regression models and drawing conclusions

Results and Discussions

The Spread of Private Car Ownership

The data used in this research was secondary data from the Central Bureau of Statistics, published on the internet. The Vehicle Ownership Data in the Province of Aceh in 2021 consisted of 23 Regencies/Municipalities. The description of the Vehicle Ownership Data in the Province of Aceh is shown by a map based on the geographical location of the Regencies/Municipalities as follows:

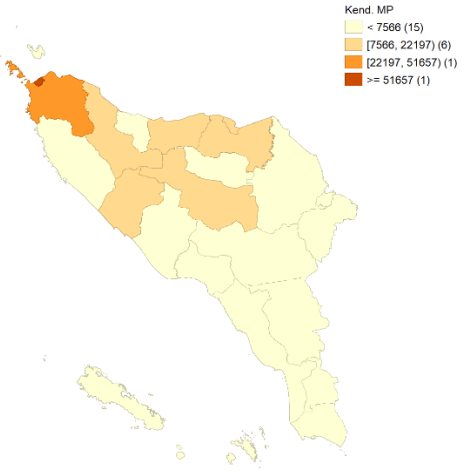

Figure 1. *The mapping of the number of private cars*

The output from the GeoDa software shows that the darker the color on the map, the higher the ownership of vehicles in a particular area(Mariani & Fauzi, 2017). This is further presented in Table 1 for clarity.

Table 1.
The spread of private cars in the Province of Aceh

Color	Area	Number of Regency/ Municipality	Name of Regency/ Municipality
	Very high	1 Regency/ Municipality	Banda Aceh City
	High	1 Regency/ Municipality	Aceh Besar
	Medium	6 Regencies/ Municipalities	Aceh Tengah, Aceh Utara, Bireuen, Lhokseumawe City, Pidie dan Aceh Barat
	Low	15 Regencies/ Municipalities	Aceh Barat Daya, Aceh Jaya, Nagan Raya, Simeulue, Kota Langsa, Aceh Singkil, Subulussalam City, Aceh Selatan, Pidie Jaya, Aceh Tenggara, Bener Meriah, Aceh Tamiang, Aceh Timur, Gayo Lues, dan Sabang City

Based on Table 1 above, private vehicle ownership is high in Banda Aceh. It can be concluded that Banda Aceh, which is the center of all economic, political, social, and cultural activities influencing the economic movement, is experiencing an increase. Therefore, many people from outside the area are settling in Banda Aceh.

Pearson Correlation Testing

The purpose of the Pearson correlation test is to determine the significant impact of the dependent variable on the independent variable. The results of the Pearson correlation test are presented in Table 2.

Table 2.
Pearson correlation analysis

Variable Definition	Correlation Value	Description

Ownership of Private Cars (Y1)		
Total Population (X1)	0.333	Weak
Regional Income (X2)	0.741**	Strong
Wages/Salary (X3)	0.656**	Strong
Area Size (X4)	-0.256	Weak
Road Length (X5)	-0.064	Very Weak
Age >17th (X6)	0.408	Medium

Table 2 indicates that among the six variables used in this study, two independent variables significantly affect the ownership of private cars, including the amount of local revenue (X1) and salary (X3). These variables will be used in further analysis.

Private Car Ownership

Based on the results of the Lagrange Multiplier statistical test, it can be shown that the spatial autocorrelation in the spatial lag is significant with a p-value of 0.04101, which is less than 0.05. On the other hand, the p-value for spatial autocorrelation in the spatial error is greater than 0.05, which is 0.08167, indicating that the spatial autocorrelation in the spatial error is not significant. From the Lagrange Multiplier test, it can be concluded that the modeling is less accurate using the OLS method as OLS ignores the spatial aspect of the data. Therefore, the modeling is completed using the Spatial Autoregressive (SAR) and Spatial Error (SEM) regression methods(Yusnita, Roza, & Rusli, 2020).

Moran Scatter Plot

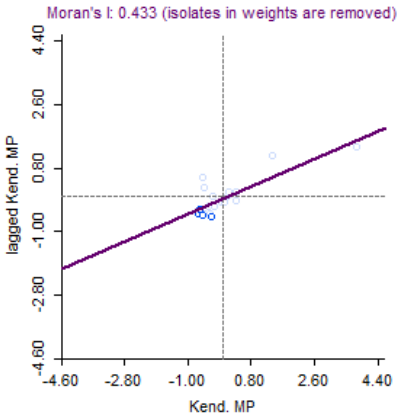

Figure 2. *Moran scatter plot*

According to Figure 2, 5 regencies/municipalities have positive spatial autocorrelation, with one regency/municipality located in quadrant I and four regencies/municipalities located in quadrant III. For a clearer explanation, it is presented in Table 3.

Table 3.
Moran's scatter plot results

Factor	Indicator
Quadrant I (High-High)	Banda Aceh Municipality
Quadrant III (Low-Low)	Subulussalaam Municipality, Aceh Selatan Regency, Aceh Tenggara Regency dan Gayo Lues Regency

The regencies/municipalities in quadrant I indicate that Banda Aceh Municipality has a high rate of private car ownership and is surrounded by neighboring areas with a high rate of private car ownership. The regencies/municipalities in quadrant III indicate that Subulussalaam Municipality, Aceh Selatan Regency, Aceh Timur Regency, and Gayo Lues Regency have a low rate of private car ownership and are surrounded by neighboring areas that also have a low rate of private car ownership.

Spatial Error Model (SEM)

The Spatial Error Model (SEM) is a spatial regression model with spatial dependence through errors. This means that SEM arises when the error values in one area are correlated with the error values in the surrounding area, or in other words, there is a spatial correlation among errors. This is further presented in Table 4.

Table 4.
The results of the spatial error regression model

Variable	Coefficient	Probability	Description
Constant	3.28	0.385	
Total Population (X1)	-2.98	0.000	Significant
Regional Income (X2)	1.588	0.000	Significant
Wages/Salary (X3)	0.993	0.719	Not Significant
Area Size (X4)	0.256	0.155	Not Significant
Road Length (X5)	-1.348	0.000	Significant
Age >17th (X6)	2.407	0.000	Significant
LAMBDA	0.835	0.000	Significant
significance α = 0.05			

Based on Table 4, the resulting model is $y_i = 3{,}28 - 2{,}298X_1 + 1{,}588X_2 - 1{,}348X_5 + 2{,}407X_6 + \varepsilon_i + \mu_i$, where ui = 0,835, $\sum_{j-1,i-j}^{n} w_{ij}\, u_j$. The coefficient of the population is 2.298. This means that for every 1% increase in population, private vehicle ownership in each regency/municipality will decrease by 2.298%. The coefficient of regional income is 1.588. This means that for every 1% increase in regional income, private vehicle ownership in each regency/municipality will increase by 1.588%. The coefficient of road length is 1.348. This means that for every 1% increase in road length, private vehicle ownership in each regency/municipality will decrease by 1.348%. The coefficient of age over 17 years is 2.407. This means that for every 1% increase in the age above 17 years, private vehicle ownership in each regency/municipality will increase by 2.407%.

The matrix w_ij u_j can be interpreted as the impact of the change in the spatial residual in the neighboring areas of a regency/municipality on the number of private vehicle ownership in that regency/municipality. In other words, if the spatial residual in the neighboring area of a regency/municipality increases or decreases, then the ownership of motor vehicles in that regency/municipality will also increase or decrease. Based on the calculation of the Wy matrix using a spatial regression model that contains dependence, there are 23 spatial regression models for each regency/municipality with its neighboring area using SEM that have been included in the equation. The models for the 23 regencies/municipalities can be seen in Annex B.3.11 as an example of the interpretation of SEM for Aceh Besar Regency is: : $\boldsymbol{y_{11} = 3,28 - 2,298X_1 + 1,588X_2 - 1,348X_5 + 2,407X_6 + +0,278u_2 + 0,278u_8 + 0,278u_{10}}$

The interpretation for the SEM in the Aceh Besar Regency region is that if the spatial residual in Aceh Jaya Regency (u_2) increases by 1%, then the spatial residual in Bireuen Regency will increase by 0.278%, assuming the other variables remain constant. The same goes for the influence of Pidie Regency (u_8) and Banda Aceh Municipality (u_10) on Aceh Besar Regency, which can be interpreted similarly.

Conclusion

The high concentration of private vehicle ownership was observed in Banda Aceh City, which can be concluded that Banda Aceh City, being the center of all economic, political, social, and cultural activities, has experienced an increase in economic activity. This results in an influx of people from outside the area settling in Banda Aceh City. In the spatial error regression model, the influence of spatial correlation was accommodated by incorporating the spatial weighting variable Lambda. The Probability value for this variable is 0.0000 < 0.05, indicating evidence that the addition of this variable has a significant impact on the model. Additionally, in the Diagnostic for Spatial Dependence, the values under the Probability column also show a value of 0.00014 > 0.05. Furthermore, based on the R-Square value of the spatial error model 0.919778 or 91%, it can be concluded that the Spatial Error Model (SEM) provides a better estimate. The Spatial Error Model (SEM) equation is based on the best regression model with an AIC value of 107.909, with the following equation.: $y_i = 3{,}28 - 2{,}298X_1 + 1{,}588X_2 - 1{,}348X_5 + 2{,}407X_6 + \varepsilon_i + \mu_i$.

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