Exploring Spatial Variation in Socioeconomic Determinants of Private Car Ownership

Masoud Ghodrat Abadi (Corresponding Author)
Graduate Student and Researcher
Scholl of Civil Engineering
Sharif University of Technology
Azadi Avenue, Tehran, Iran
+98-912-2844756
mgh.abadi@yahoo.com

Mohammad Kermanshah
Professor
Scholl of Civil Engineering
Sharif University of Technology
Azadi Avenue, Tehran, Iran
+98-21-66164181
mkerman@sharif.edu

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ABSTRACT

In Iran, as a developing country, private car ownership has increased significantly over the last two decades. This rapid growth has imposed considerable strains on traffic networks and also has indirectly created critical conditions in traffic safety. In order to capture an appropriate understanding of the main socio-economic factors of this growth, this study aims to model zonal private car ownership and examine spatial variation in its determinants across 560 Traffic Analysis Zones (TAZ) in Tehran with the application of a local model, Geographically Weighted Regression (GWR). Using land value as a proxy for average level of income in a TAZ, this paper reveals that there is a geographical distribution in relationship between per capita private car ownership and income, indicating that in low-income TAZs, instead of income, demographic structure and social needs of TAZ’s inhabitants are the major determinants of private car ownership. Conventional technique of linear regression is also applied to model private car ownership and is compared to GWR. This comparison demonstrates that GWR surpasses linear regression.
INTRODUCTION

The rise in private car ownership has been impressive over the last two decades, especially in developing countries. Several different factors have been recognized as the reasons of sharp growth in private car ownership and use, among them, increase in level of personal income, improvement in socio-demographic structure of households, reduction of urban population density and lack of a robust public transit system are widely accepted as keystones (1, 2, 3). In Iran, as a developing country, private car ownership has increased significantly over past years. In capital city, Tehran, while 0.17 private cars per capita were estimated in 2007, by 2012 this increased to 0.25. Figure 1 exhibits the increasing trend in private car ownership for the period of 1991 to 2008 in Tehran.

Rapid growth in private car ownership and use, besides the inadequacy of appropriate transportation infrastructures has created a critical condition in Iran. In urban streets, limited capacity of street networks is not able to compete with such an increasing travel demand. Inevitable consequence of this problem would be formation of traffic jams which inherently means squandering of time, creating stress, more energy consumption and environmental pollution. In rural roads also, severe accidents and critical issues related to traffic safety are indirect consequences of increasing private car ownership and use. According to the facts mentioned above, a basic understanding of different factors influencing car ownership would be beneficial in effective policies and successful urban planning.

In order to capture an appropriate understanding of the main socio-economic factors of this growth, in this paper, a relatively new technique, Geographically Weighted Regression (GWR), which addresses the issue of spatial variability, is employed to model private car ownership and explore causal factors and the way in which they affect private car ownership. This model is developed across 560 Traffic Analysis Zones (TAZ) in Tehran.
LITERATURE REVIEW

Models to predict changes in car ownership, an essential input to transport planning, have been under development since the early 1940s (4). From an overall prospect, based on the level of aggregation, car ownership models can be divided into aggregate and disaggregate models.

Aggregate models are unsophisticated models which are generally developed for the practical issues and their calibration process does not require heavy data. Aggregate models can be divided into two distinct categories: aggregate cross sectional models and aggregate time series models. Aggregate cross sectional models are developed at a specific section of time and in a geographical distribution. They are mostly developed using conventional technique of linear regression (5, 6) but similar other structures are also employed in this section (7, 8). Aggregate time series models usually apply a sigmoid-shape function and also the concept of car ownership saturation level for development of car ownership over a period of time (2, 9, 10).

Disaggregate models are newer approaches in comparison to corresponding aggregate models. These models often contain behavioral models, are usually developed at the household level and are benefited from a strong theoretical background. Static and pseudo dynamic models and then dynamic models are two distinct classification of disaggregate models. Discrete choice techniques are widely used in static and pseudo dynamic disaggregate models (11, 12, 13, 14). Dynamic disaggregate models are modern approach in car ownership modeling in which transaction time is the most important variable (15, 16).

In developing countries, due to lack of appropriate disaggregated data, car ownership modeling is usually at the aggregate level. However, using conventional techniques in aggregate study would totally mislead the planners from getting details of main factors in private car ownership. In a parallel effort to advanced disaggregate models, an aggregate approach, Geographically Weighted Regression (GWR) (17) which is a relatively new structure in modeling spatial variation, is utilized in this paper. This method is widely employed in different areas such as social science (18), Ecology (19) and transportation planning (20, 21, 22). GWR model produces a set of local estimates by including spatial coordinates into global linear regression and also by the help of a series of distance related weights in a weighted least square process. In the case of car ownership studies, there is an only application of GWR (8) which utilized cross sectional data through United Kingdom electoral wards. Based on observed spatial correlations in the residuals of global linear regression model, that study employed GWR technique to estimate car ownership. It just investigated the spatial pattern of income and finally suggested that for “local planners who need to predict future car ownership levels, for example to plan future roads and parking provisions or forecast the use of public transport, the local GWR estimates will be more appropriate”.

METHODOLOGY

The technique of linear regression has been employed as the most common type of analysis to identify relationships between one or more independent or explanatory variables and a single dependent variable. A global regression model may have the following form:
where, $y$ : dependent variable, 
$\beta_j$ : the $j$-th model parameter ($j = 0, 1, \ldots, k$), and 
$x_j$ : the $j$-th explanatory variable ($j = 1, \ldots, k$).

In regression models, where the observations are related to geographical locations, 
regression coefficients might vary over space, but the technique of linear regression itself, 
takes no account of spatial variation in its analysis of relationships between variables. On the 
contrary, while predicting the dependent variable $y$ by the help of a set of explanatory 
variables in a GWR model, coefficients $\beta_j$ ($j = 0, 1, \ldots, k$) could vary by each geographical 
location. In this way, at first a set of coordinates $(u_i, v_i)$ is assigned to each observation $i$ to 
actually address a geographical location and then $y_i$ is predicted as:

$$
y_i = \beta_0(u_i, v_i) + \beta_1(u_i, v_i)x_1 + \beta_2(u_i, v_i)x_2 + \ldots + \beta_k(u_i, v_i)x_k
$$

In this equation, $\beta_j$ ($j = 0, 1, \ldots, k$) is a function of geographical location $(u_i, v_i)$. This 
means that based on the spatial variation in observations, the equation may produce different 
predictions for dependant variable $y$ with the same set of explanatory variables $x_j$ ($j = 1, \ldots, k$).

To estimate local coefficients $\beta_j$ ($j = 0, 1, \ldots, k$) in a GWR model, a specific weighting 
function which is also known as a kernel function is employed. The main notion behind the 
GWR model is that for each geographical observation $i$, there is an area of inclusion around $i$, 
which is a production of the weighting function. The main trait of this area of inclusion is that, 
those observations which are geographically near to observation $i$ have more influence in the 
estimation of $i$’s coefficients than do those located farther away. The depth of inclusion area 
which is sometimes also referred to as the kernel bandwidth can be determined by utilizing a 
number of data-driven criteria, including corrected Akaike Information Criterion (AIC_C), 
Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC) and Cross 
Validation (CV).

The depth of inclusion area could be estimated in two ways. A fixed distance-based 
bandwidth which accounts for observations located in a specific fixed distance from a 
regression point and a fixed neighboring-based bandwidth which accounts for a specific fixed 
number of the nearest observations neighboring a regression point. Fixed bi-square (equation 
3) and adaptive bi-square (equation 4) functions are two of distance-based and 
neighboring-based weighting functions, respectively:

$$
W_y = \begin{cases} 
(1 - (d_{ij}^2 / \theta^2))^2 & d_{ij} \leq \theta \\
0 & d_{ij} > \theta 
\end{cases}
$$

$$
W_y = \begin{cases} 
(1 - (d_{ij}^2 / \theta_{ij}^2))^2 & d_{ij} \leq \theta_{ij} \\
0 & d_{ij} > \theta_{ij} 
\end{cases}
$$

$$
W_y = \begin{cases} 
(1 - (d_{ij}^2 / \theta_{i(ki)}^2))^2 & d_{ij} \leq \theta_{i(ki)} \\
0 & d_{ij} > \theta_{i(ki)} 
\end{cases}
$$
where,

\[ W_{ij} \] : weight of observation at location \( j \) for estimating coefficient at location \( i \),

\[ d_{ij} \] : Euclidean distance between observations \( i \) and \( j \),

\[ \theta \] : fixed bandwidth defined by distance, and

\[ \theta_{ijk} \] : adaptive bandwidth defined as the \( k \)-th nearest neighboring distance

CASE STUDY: PRIVATE CAR OWNERSHIP IN TEHRAN, IRAN

This study utilizes the cross sectional data of Tehran's transportation master plan conducted in 2007, in which Tehran is divided into 560 Traffic Analysis Zones (TAZ). Tehran dominates as a primate city across the country which is the center of administrative, social, commercial, industrial and cultural activities. In 2007, Tehran with about 7.7 million residents was the most populated city throughout Iran. This population owned about 1.3 million private cars which means in 2007, per capita private car ownership in city of Tehran was about 0.17. Figure 2 exhibits spatial variation of per capita private car ownership across 560 TAZs in Tehran.

![Spatial variation of per capita private car ownership in Tehran.](image)

Figure 2 illustrates that the amounts of per capita private car ownership in Tehran, are much greater in northern areas than those in southern areas. Indeed Tehran represents a special socio-geographic phenomenon in which northern areas are extremely different from southern areas in several aspects including urban design, quality of life, economical situation, social welfare and even weather condition. Northern areas are spread in foothills of mountains, have a pleasant weather, are sparsely populated and have a modern urban structure and high social class, whereas southern areas are environmentally polluted areas which are highly populated and suffer from an old inefficient urban design. Households inhabit in northern areas usually posses higher socio-economic characteristics and have a better living and behave in a different way in comparison to corresponding households.
inhabit in southern areas. Therefore, considering the same effect for socio-economic determinants of car ownership among different areas could be misleading.

**VARIABLE ACQUISITION**

**Definition**

Among available variables, four explanatory variables with a socio-economic background are selected to model per capita private car ownership as the dependent variable across 560 TAZs in Tehran. Table 1 presents a brief introduction for each variable.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Explanation</th>
<th>Unit</th>
<th>Descriptive Statistics</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCPCO</td>
<td>Zonal per capita private car ownership</td>
<td>Private cars/Person</td>
<td>0.026 0.170 0.487 560</td>
<td></td>
</tr>
<tr>
<td>LVAL</td>
<td>Land value</td>
<td>100,000Rial/m²</td>
<td>0.125 1.128 3.390 560</td>
<td></td>
</tr>
<tr>
<td>POPDEN</td>
<td>Population density</td>
<td>Persons/m²</td>
<td>0.001 0.020 0.054 560</td>
<td></td>
</tr>
<tr>
<td>DL</td>
<td>Ratio of individuals with driving license by TAZ population</td>
<td>-</td>
<td>0.098 0.385 0.850 560</td>
<td></td>
</tr>
<tr>
<td>U18</td>
<td>Ratio of individuals aged fewer than 18 by TAZ population</td>
<td>-</td>
<td>0.093 0.298 0.545 560</td>
<td></td>
</tr>
</tbody>
</table>

Although income is one of the most important explanatory variables in car ownership modeling, in Iran due to constraint of a developing country, there is no available recorded data on the level of income, even at aggregate level. In order to find a proxy for income, land value (LVAL) for each TAZ is introduced.

**Land Value**

In transportation literature, when the concept of land value is employed, in most of the cases, the goal is to explore the effect of development of a new transportation infrastructure on the improvement of land value in nearby vicinity (23, 24). However in this study, land value is utilized in a different way. Here land value is selected as a representative of average level of income and its effect on private car ownership is examined. Indeed it is anticipated that households with higher level of income and better economical situation reside in better parts of city which are valued more. This is correct, especially for city of Tehran where due to a weak and inconvenient transportation system, land value is not much affected by transportation infrastructures or public transit and is mainly developed through social conventions.

Employing land value for TAZs, one might face a problem. TAZs are defined based on current street networks and traffic conditions and consequently there is a non-stationary of land value in different parts of a TAZ. Reaching a unique measure of land value at each TAZ,
the amount of the tax which is taken by Tehran's municipality from per square meter of newly built houses in each area is utilized. This amount is defined in a way that is absolutely in linear correlation with land value and is also constant for each TAZ. Figure 3 exhibits the spatial variation of land value across Tehran, based on five categories. It shows that northern areas are valued more than those in southern parts in term of land tax value.

FIGURE 3 Spatial variation of land value within Tehran.

GLOBAL LINEAR REGRESSION MODEL

Following studies on aggregate cross sectional modeling of car ownership, conventional linear regression based on the ordinary least squares (OLS) method is first utilized to examine the simultaneous effects of the four explanatory variables on car ownership. The linear regression results are summarized in Table 2.

TABLE 2 Global Linear Regression Model of per Capita Private Car Ownership

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>t - statistic</th>
<th>p - value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVAL</td>
<td>0.056</td>
<td>16.030</td>
<td>0.000</td>
</tr>
<tr>
<td>POPDEN</td>
<td>-0.784</td>
<td>-5.675</td>
<td>0.000</td>
</tr>
<tr>
<td>DL</td>
<td>0.335</td>
<td>18.746</td>
<td>0.000</td>
</tr>
<tr>
<td>U18</td>
<td>0.042</td>
<td>1.670</td>
<td>0.095</td>
</tr>
<tr>
<td>Intercept</td>
<td>-0.010</td>
<td>-0.787</td>
<td>0.431</td>
</tr>
</tbody>
</table>

F test 520.736
Adjusted $R^2$ 0.788
AIC$_C$ -2027.1
The ANOVA $F$ test indicates statistical significance for overall model and the value of adjusted $R^2$ (0.79) suggests an appropriate goodness-of-fit. Parameter estimates indicate that land value ($LVAL$), ratio of individuals with driving license by TAZ population ($DL$) and ratio of individuals aged fewer than 18 by TAZ population ($U18$) are significantly and positively associated with zonal per capita private car ownership ($PCPCO$) while population density ($POPDEN$) has a strong negative influence.

As it was mentioned earlier, $LVAL$ is employed as a representative of average level of income in a TAZ. In other words the more the value of land, the higher the average level of income and in a same interpretation the more the level of income, the more the level of private car ownership. Achieving a significant positive coefficient for $LVAL$ acknowledge this assumption.

Different forms of population density has been widely employed and interpreted in studies of car ownership modeling. From a point of view, population and job density is used to address the accessibility of public transit. From another aspect, population and job density is applied to explain free parking spaces in an area in a way that more available on-street parking spaces are anticipated in less condensed areas. Last but not least, especially for Iran, as well as other developing countries, population density could be used as a proxy for income hence sparsely populated areas are those belong to higher social classes and better urban designs. As indicated in Table 2, $POPDEN$ is reversely related to zonal per capita private car ownership in Tehran, which means better accessibility to public transit, less available on-street parking spaces and lower level of income lead to less zonal private car ownership.

Explanatory variables which are defined to address licensed drivers, play an important role in almost all merited car ownership models. People with driving license are those who are potentially eligible for driving a car and one would logically assume that increase in the proportion of persons with driving license from population of a TAZ, would increase the level of per capita private car ownership in that area. Positive sign in coefficient of $DL$ presents the same interpretation.

To address the age structure of a TAZ and its influence on car ownership, the variable $U18$ is employed. The positive sign of coefficient for this variable suggests that increase in proportion of persons aged fewer than 18 from TAZ population would increase the level of private car ownership. It could be assumed that more presence of younger population in an area, especially those who are aged fewer than 18 would increase the level of car ownership because of additional needs for non-working trips and also because teenagers depend on adult household members for their mobility.

As indicated in Table 2, intercept is not statistically different from zero and subsequently is not statistically significant, but to keep the properties of other explanatory variables, it is remained in the model.

**GEOGRAPHICALLY WEIGHTED REGRESSION MODEL**

The global regression model assumes that the observed relationships between per capita private car ownership and each explanatory variable are identical in all TAZs and cannot be used to explore spatial variations in regression model coefficients. The same dependent variable and set of independent variables from the global regression model were utilized to
develop the GWR model. The GWR 4.0.70 software (26) was used to calibrate local regression models.

The numerical results associated with GWR analysis of per capita private car ownership in 560 TAZs across city of Tehran are summarized in Table 3. For the model results reported below, the adaptive bi-square kernel function, where a constant number of neighboring TAZs are used in the estimation process, is employed in preference to the fixed distance kernel functions which use all TAZs within a constant distance. The main reason for this choice is that for those TAZs which are located in peripheral areas, the fixed distance approach in GWR process, includes too few neighboring TAZs which would lead to an ill-defined estimation problem and for those TAZs that are located in dense central areas, the GWR process includes too many TAZs which could totally weaken the local nature of relationships. The corrected Akaike information criterion ($AIC_c$) is used for selecting the optimal kernel size. The GWR model is fitted to these data, adapting the bandwidth of the kernel to ensure that 52 observations (this is 8% of total number of TAZs) are included in all the regression estimates.

**TABLE 3 Geographically Weighted Regression Model of per Capita Private Car Ownership**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficients</th>
<th>Percent of TAZs by significance (95% level) of t-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Median</td>
</tr>
<tr>
<td>$LVAL$</td>
<td>-0.098</td>
<td>0.046</td>
</tr>
<tr>
<td>$POPDEN$</td>
<td>-3.478</td>
<td>-0.313</td>
</tr>
<tr>
<td>$DL$</td>
<td>-0.063</td>
<td>0.246</td>
</tr>
<tr>
<td>$U18$</td>
<td>-0.199</td>
<td>0.028</td>
</tr>
<tr>
<td>Intercept</td>
<td>-0.262</td>
<td>0.030</td>
</tr>
</tbody>
</table>

Adjusted $R^2$ 0.885
$AIC_c$ -2281.7
Number of effective parameters 98.709

In this table, standard t-statistic values of -1.96 and +1.96 are used to represent the 95% level threshold for negatively and positively significant relationships, respectively. For instance, land value ($LVAL$) is positively and significantly related to per capita private car ownership in about 54% of TAZs, it is also negatively and significantly related to per capita private car ownership in about 1% of TAZs and is not significant in any of the remaining TAZs. Based on the significance of t-statistic, $DL$ is the best explanatory variable which has a significant positive effect on per capita private car ownership in 85% of all TAZs.

**SPATIAL VARIATION**

The GWR allows us to examine the spatial variation within the study area for each individual model coefficient. For example, global regression model estimated the parameter for $LVAL$ to
be significant and equal to 0.056 for the entire city. However, the local regression models show that the coefficients for this variable range from -0.098 to 0.174 across TAZs in Tehran with a median of 0.046 (Table 3). This variability in the model parameter suggests that the relationship between the land value and private car ownership is not stationary within the city at the TAZ level. As it was mentioned earlier, $LVAL$ is employed as a proxy for average level of income in a TAZ. Figure 4 exhibits the spatial variation of the coefficient for the variable $LVAL$ within the 560 TAZs in four categories based on observed values in linear regression and GWR estimation.

![FIGURE 4 Spatial variation of $LVAL$’s coefficient in GWR model.](image)

Figure 4 depicts that coefficients for $LVAL$ have taken positive values in most of TAZs (87% of total TAZs). This means that in most of the local regressions, similar to what was achieved in global linear regression, land value has a positive effect on per capita private car ownership. One would anticipate such a same effect for the average level of income on the private car ownership, therefore utilizing land value as an appropriate proxy for average level of income which was introduced and supported earlier in this study for Tehran, does not seem to be incorrect.

In order to explore the spatial variation of the income’s effect on private car ownership, Figure 5 illustrates the geographical distribution of $LVAL$’s $t$-statistic values across Tehran. As indicated in this figure, while income in northern areas in which both the private car ownership and land value are at a high level, presents a significant positive effect and is a great explanatory variable, in southern areas in which both the private car ownership and land value are at a low level, despite the positive effect, it is not a complete explanatory variable.

Generally speaking, figures 4 and 5 depict that although income has a positive influence on private car ownership in almost everywhere, for TAZs and subsequently households with lower level of income, who own private cars, there are some other socio-economic factors rather than income which influence private car ownership. In other words, considering the same effect of income, as the most important explanatory variable, on private car ownership without paying attention to other socio-demographic characters of a household would be totally misleading.
Finding the spatial pattern for influence of other determinants, in figure 6, for each explanatory variable, a map is generated that represents the spatial variation of the $t$-statistic value across Tehran.

Among the TAZs in which income does not provide a perfect explanation of owning private cars, in peripheral southern TAZs, the variable $U18$ which addresses the proportion of persons aged fewer than 18 and subsequently the younger structure of a TAZ (Figure 6c), in south-eastern TAZs the variable $DL$ which addresses the proportion of licensed drivers (Figure 6b) and finally in central TAZs, population density ($POPDEN$) (Figure 6a) have a significant effect and are perfect explanatory variables.

The important effect of variables $DL$ and $U18$ in southern TAZs which are mostly resided by households with lower level of income, demonstrates that owning a private car in a household is not just affected by the level of income, but in many cases it is mainly based on household’s structure and social needs. For these TAZs it seems that despite the financial limitations, a household’s younger structure and presence of more members with driving license, force the households to own private cars to fulfill their needs. The owned car might be a second handed one which does not cost much or might be purchased and paid through installment and even might be an assistant for household livelihood. In central TAZs, which are the most condensed areas in Tehran, $POPDEN$ is a perfect explanatory variable which has a significant reverse influence on private car ownership. These central areas of Tehran posses the best availability of public transit (which is provided as BRT lanes and subway corridors) and also serve few on-street parking spaces. According to what was outlined previously about population density and based on the real urban characteristics of central areas of Tehran, one would conclude that better accessibility to public transit and fewer on-street parking spaces would decrease the level of per capita private car ownership just in absolutely condensed areas.
The GWR software package calculated the global AIC$_C$ as -2027.1 with five parameters. The AIC$_C$ for the GWR model is -2281.7 on 98.7 effective parameters which represents an improvement in fit. The global adjusted $R^2$ value has also increased from 0.79 to 0.89 in GWR model. In order to evaluate the ability of models in prediction of observations, a comparison criterion is used in which the amount of observation at each TAZ is subtracted from model prediction and is finally divided by amount of observation. This measure of effectiveness could show the deviation in observed values and model predictions. Table 4 demonstrates the descriptive statistics of this measurement for each of two models.

<table>
<thead>
<tr>
<th>Model</th>
<th>Descriptive Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
</tr>
<tr>
<td>Linear Regression</td>
<td>-4.790</td>
</tr>
<tr>
<td>GWR</td>
<td>-1.815</td>
</tr>
</tbody>
</table>

As indicated in this table, GWR surpasses the conventional linear regression in...
accurate prediction. For example, while the median of comparison criterion in linear
regression is 0.015, in GWR this amount is almost zero. Generally speaking, GWR
outperforms the traditional linear regression in almost all aspects, which demonstrate that
GWR technique is not only appropriate to examine spatial variation in interaction between
dependant variable and explanatory variables but also a better approach in aggregate cross
sectional car ownership modeling.

SUMMARY AND CONCLUSION

Rapid growth in private car ownership and use, besides the inadequacy of appropriate
transportation infrastructures are the main reasons for urban congestions. Devising an
effective urban plan requires a thorough understanding of factors which influence owning
private cars and the way in which they affect private car ownership. In order to achieve this
goal, in this paper, the technique of GWR which addresses the issue of spatial variability is
employed across 560 TAZs in Tehran. Different geographic areas in Tehran represent diverse
socio-economic characters and considering the same effect for determinants within different
areas would be misleading.

Four explanatory variables with socio-economic background are selected to model
private car ownership. Applying land value as a proxy for income and exploring the spatial
variation in its effect reveal that although income has a positive effect on private car
ownership in almost everywhere, it is not a statistically significant explanatory variable in
low-income TAZs. In these areas, variables which address socio-demographic characters of
inhabitants of the area such as proportion of licensed drivers and proportion of persons aged
fewer than 18 are pertinent variables, suggesting that owning a private car is not just affected
by the level of income, but in many cases it is mainly based on household’s structure and
needs. Exploring the effect of population density indicates its significantly reverse influence
on private car ownership just in the most condensed areas.

Conventional technique of linear regression is also applied and compared to GWR.
Based on the amount of AIC C and adjusted \( R^2 \) and also the ability of models in prediction of
observations, GWR surpass global linear regression.

Finally, it should be mentioned that the fact of owning a private car, especially in
developing countries is somehow a complex process which is not only affected by
economical situations, but also by social needs. This makes the car ownership studies a
challenging topic which requires the application of sophisticated methods that are able to
shed light on all the aspects of this subject. There are many academic researches as well as
practical studies, even at the level of households, which just counts on income to model car
ownership or even take car ownership as a trusted proxy for level of income. However, these
kinds of studies might be losing a big part of a baffled jigsaw puzzle.

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