The Influence Change of Private Car Ownership on Patterns of Mode Choice in Baghdad city

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Abstract. The growth rate of vehicle ownership in Baghdad has increased since 2003. For the analysis of adverse effects of car ownership on transport mode choice, the comparison between the patterns of mode choices in the past with current situation was studied. The transport mode choice was calibrated using a Logit model; it combines different characteristics of the alternatives and individual socioeconomic variables in a meaningful way to calculate a utility value. The model requires data of zones, choice data of travelling mode and the selected mode attributes. Trans Cad was used to calibrate the utility functions, MNL analysis in Trans Cad is used to develop the model. The travelling modes used in the study area are private mode (car) and public mode (bus). The level of service variables (In-vehicle travel time, cost) and socioeconomic variables (auto ownership, income) are used. After calibration of the split model, the process of validation is achieved by comparing field measured modal split of traffic volumes with estimated split results of the model. The results show that a higher share of public transport in the past, while in 2014, it appears that the share of auto is higher. Through these results, it finds that public transport must be given the utmost importance in order to provide a sustainable environment in the region.

1. Introduction

Baghdad is experiencing rapid urbanization, economic growth, and motorization between 1976 and 2014. In 1976, the population of Baghdad was 2.5 million and since that time, it experienced a growth of 7 million people until 2014, this increase in population will result in urbanization, increase in daily activities and increase in trip rate. In recent years, travel behavior of mode choice is changing due to rising income and auto ownership. The automobile represents the main mode selected by large numbers of individuals to travel in Baghdad city. Due to high auto dependency, it leads to high demand on all highways and accordingly will increase the traffic congestion. Congestion is a serious global problem; it is a result of the increase in the use of the automobile, in addition to that, lacks in the public service infrastructure, which has adverse effects on travel time, vehicle operation costs, the inconvenience of drivers, air quality, etc. The inability to expand and build additional infrastructure, due to high capital costs, the right of way constraints and environmental considerations, accordingly severe traffic congestion continued. Therefore, there is a need to analyze the mode share in Baghdad city. Analysis and modeling of travel mode choice between the past and the current situation is the objective of this study. The mode choice in Baghdad depends on demographic and socioeconomic factors. The research methodology is based on a mode choice model developed for the Baghdad city in 1976 and 2014. In order to understand the shift in mode share and try to choose the correct policies to solve the congestion problem.

The main objectives of the study are as follows:

1. To study the behavior of individuals to choose the travel mode.
2. To identify the attributes influencing the mode choice behaviors.
3. To prepare Multinomial Logit Models (MNL) for two type modes of transport.

2. Background
Mode choice is an important role in the transportation planning process. In any region, it influences the transportation scenario by deciding which feasible policies to use. Mode choice is affected by more than one factor, like person socioeconomic characteristics and trip characteristics. Person socioeconomic characteristics represent by income, age and auto ownership while trip characteristics represent by trip cost, the number of transfers, travel time, and trip distance. Individual socioeconomic characteristics have the main influence on mode choice behavior, travel mode decisions depend on income, gender, car ownership, employment [5]. Due to increase in car ownership rate, the use of auto motorized modes was increased. Accordingly, this effect will increase traffic congestion, noise and air pollution [20]. Development of discrete travel choice models is based on the idea that an individual is supposed to select the best mode, which gives him/her the highest utility among those available modes [4].

Many researchers study mode choice behavior and in addition to its influencing factors. [13] showed that the level of service attributes like (travel time, distance, cost) have distinctive influences on choice of transit mode. [12] studied the effect of public mode choice and transit route choice in Montreal. They studied why individuals prevent using public transit, and what are the attributes that play a significant role in route choice decisions. The model results have given recommendations to public transportation and metropolitan agencies. [13] conducted empirical models to study student's mode choice behavior. It reveals that the mobility tool and age groups have a significant influence on which mode (bike and ride) is encouraged during peak hour, accordingly a large amount of demand will be achieved for this mode. In another study, [8] study the mode share of university students and employees, he compared the effect of introducing a shuttle bus on the modal share. They found that when service frequency increased and access distance reduced, it will increase transit ridership. [3] use mode choice models to select the suitable policies to overcome congestion and to estimate the value of travel time which is used as a measure of benefits gained from reduced congestion. The means to maximize public transportation ridership will reduce the auto mode share [14].

3. Study Area
Baghdad is the capital of Iraq. It has the largest concentration of urban population in Iraq. It is the center of Iraq’s finance, commerce, and manufacturing. Tigris River is the most important natural feature in the identity of the city; it splits Baghdad to Karkh and Rusafa. The Mayoralty of Baghdad (MoB) represents the study area boundary, it represents 80% of the Governorate. It’s area equal 840 km2, the MoB population in 1997 equal to 4319633. In 1976 Swiss Consultant – De Consult (Consult, 1976) prepared a feasibility study. Swiss Consultant performed a feasibility study and presented a conventional approach to transportation forecasting based on what is commonly known as the four-step model. An integrated public transport system is recommended as the outcome of Feasibility study.

In the current study, the Study area is divided into a geographic area where the trip begins or end, it is called a Traffic analysis zone (TAZ). These areas (TAZ) are mapped in Trans CAD; travel analysis zones (TAZ) are used to subdivide the study area for the purpose of connecting land uses to the highway network. It represents areas of homogeneous land use and demographic characteristics. It’s characterized by their demographic characteristics such as population, employment, etc. TAZ is the places where trips start at zone centroid which is the start of activity in a zone, (trip producers) or end (trip attractors). A study area in the feasibility study in 1976 is divided into 9 districts and 177 internal TAZ. Figure 1 shows TAZ in 1976 according to the feasibility study.
4. Socioeconomic Data Preparation
Swiss Consultant – De Consult (Consult 1976) executed household interviews with a questionnaire developed especially for this survey. It contains in one part questions related to the demographic structure of the households and in the other part, questions to find out the trips made in one fixed day by all persons living in the household. Developing 1976 model split is based on socioeconomic characteristic and travel related data. Socioeconomic characteristic is represented by car ownership, income, and employment data. These data were collected, coded and distributed between TAZs. Socioeconomic thematic maps were prepared using Arc GIS. Figure 2 shows the socioeconomic characteristic distributed between TAZ.

5. Mode Choice Modeling
Discrete choice models describe individuals travel behavior of a discrete set of alternatives (Khan, 2007). Random utility theory is the most common theoretical base for generating discrete choice models (Domencich & McFadden, 1975). Choice set represents an available set of alternative
travelling modes where an individual can use it to travel between two places. The individual choice a specific mode based on maximizes his or her utility (Richards & Ben-Akiva, 1975). The utility is the attraction of the individual for a specific mode to conduct a specific trip (Khan, 2007). The utility is a linear function between attributes of the trip and the selected mode. The coefficients represent the relative importance as perceived by the traveler. The utility is represented as the following equation:

\[ U_{mi} = b_1x_{mi1} + b_2x_{mi2} + \ldots + b_kx_{mik} \]  

(1)

Where, \( U_{mi} \) is the utility of mode \( m \) for individual \( i \); \( x_{mi1} \ldots x_{mik} \) are \( k \) number of attributes of mode \( m \) for individual \( i \); and \( b_1 \ldots b_k \) are \( k \) number of coefficients for each attribute which need to be estimated from the model. Two statistical methods (likelihood and least-squares regression methods) used to estimate the unknown coefficients. The application of these models relies on the structure of the probability functions.

5.1 Multinomial Logit Models
Multinomial Logit models are the most practical models used to estimate the modal split between more than one alternative. It is simple models based on extreme value distribution, these models assume all terms have identically distributed and independently (Domencich & McFadden, 1975). The independence irrelevant alternative is a property which means choosing alternative \( i \) over alternative \( j \) must not be depending on the choice set for all set of pair zones (Luce, 1959).

Binary choice models are one of multinomial choice models. In these models, a set of two alternatives is available, and the individual must select one of the alternatives. The form of equation as follows:

\[ P_n = \frac{e^{V_n}}{\sum e^{V_m}} \]  

(2)

Where, \( V_n \) is the utility of mode \( n \); \( V_m \) is the utility of any mode; \( P_n \) is the probability when the individual want to selects mode \( n \); and \( m \) is the set of all alternative modes.

5.2 The Conditional Logit Model
McFadden (1973) proposed modeling the utilities \( U_{ij} \) according to the characteristics of the alternatives instead of characteristics of individuals. When \( z_j = \) vector characteristics of the \( j \) alternative, then he proposed the model \( U_{ij} = b z_j \). This model is named the Conditional Logit model, which is equivalent to (log linear model) where the major impact of the response is affected by the variables \( z_j \).

5.3 Multinomial/ Conditional Logsits
The multinomial logits model is used to model choice behavior by using variables includes (characteristics of the alternatives and individuals), these characteristics include travel time, income, etc. For choice among \( J \) alternatives, let \( U_j \) represent the utility of the \( j \) choice to the \( i \) individual.

\[ U_{ij} = x^r + z_a. \]  

(3)

Where \( x \) represents characteristics of the individual that are constant across choice and \( z \) represents characteristics of an alternative that vary across choice. Bruce et al. (Spear, 1977) discussed that the probability of an individual to select a specific mode is the relation between the characteristics of the individual and the overall desirability of the chosen alternative relative to other modes. It is common to use alternative specific constants (ASCs) in these models, in order to take into account the attribute that cannot be estimated and to improve model performance (Blamey et al., 1998). ASCs are not however related to specific attributes. They do not explain choice in terms of observable attributes, nor can they be easily used in predicting the effect of changes due to attribute changes (Adamowicz et al., 1998).

6. Model Specification
In 1976, choice data were analyzed using the Trans Cad MNL module. A total of 33835 cases was collected; 9935 cases were rejected due to missing values (outlier) and 23718 cases were taken for
model formulation. The MNL module was run with different attempts using various attributes to ascertain the essential attributes of the model. MNL analysis in Trans Cad uses a special statistical procedure known as Conditional Logit Model which is used to develop the model. It combines different characteristics of alternatives and individual socioeconomic variables in a meaningful way to calculate a utility value. The utility must contain:

- The socioeconomic characteristics of the decision-maker
- The attributes of each alternative
- The choice

The model requires data of zones, these data consist the choice of mode and the attributes of the selected mode.

6.1 Choosing Model Variables
Travelling modes used in the study area are private mode (car) and public mode (bus). The level of service variables (In-vehicle travel time, cost) and socioeconomic variables (auto ownership, income) are used. The mode attributes have been estimated: In vehicle travel time: It is the travel time in the mode from the origin zone to destination zone. Travel cost: It is the total cost to travel from the origin zone to destination zone. Parking cost: It is the cost associated with a car for park and it is applied at destination zone. Socioeconomic variables: They are collected for each zone: (Income and Auto ownership), they are applied at origin zone. The cost data for the 1976 model was collected from the Public Company for transport / Ministry of Transportation
Parking cost = 0.3$ at CBD and = 0.24$ at other area.
Fare Bus = 0.045$ and for Mini bus = 0.08$

7. Transit Network Development
The public passenger movement in 1976 is studied. The total number of bus route services operated along study area is drawn in Trans Cad. Trans Cad has special procedures for creating transit networks. Using route system layer (routes, stops) and highway line geographic file (street layer, node layer), the transit network is created. An important feature of the transit network analysis in Trans Cad is that fares are used to calculate the best transit paths and transit skims. A transit fare was specified as flat fare (where the fare on each route is fixed regardless of the distance traveled). Using transit networks, shortest path problems can be solved; transit path attributes (i.e. skims) can be calculated between stops in route system or nodes on the underlying line layer. The data 1976 is prepared to construct transit skims for each mode. In addition to the route system, it should include non-transit links from the underlying line layer to provide connectivity. The purpose of non-transit links in a transit network is to provide access and egress between the centroid node and the stop and to provide walk and transfer access between stops. These additional links can represent either walking links or different types of transfer links and can prepare the numeric attributes for these links (walking time, transit travel time on the links that routes traverse). Attributes of the transition paths are used for developing inputs for mode choice models. The transit shortest path results are displayed in matrix from each origin to each destination which provides the following information:

- The total generalized cost of travel between each origin and destination.
- The cash fare paid for the trip.
- The in-vehicle travel time.

8. Model Calibration
Calibration is used to estimate coefficients for each utility mode. A fixed-format binary table known as the (Trans Cad MNL table) was used to define the utility functions. Table (1) shows the format of the MNL table which consist of the first column to define the alternatives. The name of the variables was entered in the top row, and the following rows are used to specify the fields of the source data.
Table 1. The Format of the MNL table

| Alternatives | ASC | Travel Time  | Income | Fare  | Park Cost | Car ownership |
|--------------|-----|--------------|--------|-------|-----------|---------------|
| Private      | one | Skim matrix  | Income | Skim matrix | Cost | Car |
| Public       |     | Skim matrix  |       |        |           |               |

Then the utility function has the following form:

Private mode = $\beta_0 + \beta_1$ Travel Time + $\beta_2$ Car ownership + $\beta_3$ Park Cost

Public mode = $\beta_1$ Travel Time + $\beta_2$ Income + $\beta_3$ Fare

8.1 Sample Size Requirement

According to Hosmer Jr et al. (2013), for each independent variable, the minimum number of cases should be greater than 10. In our case, the requirement was satisfied.

8.2 Multi Collinearity

The standard errors of the $b$ coefficients are examined to check for multi-collinearity in the multinomial logistic regression. A value greater than 2.0 pointed out to multi-collinearity problems. As shown in Table (2), there is no variable had a standard error larger than 2.0.

9. Modal Split Analysis

The following set of equations is a result of the utility function of MNL models

Private mode = -4.871184 - 0.164058 $\beta_1$ + 3.048159 $\beta_2$ - 8.112157 $\beta_3$

Public mode = -0.164058 $\beta_1$ - 0.003125 $\beta_2$ - 9.974343 $\beta_3$

Table 2. Results of MNL Model

| Parameter | Estimate | Std. Err. | t Test  |
|-----------|----------|-----------|---------|
| ASC       | -4.871184| 0.310482  | -15.689086 |
| Travel Time | -0.164058 | 0.002740 | -59.868601 |
| Income    | -0.003125 | 0.000217 | -14.426157 |
| Car ownership | 3.048159 | 0.152559 | 19.980144 |
| Fare      | -9.974343 | 0.842453 | -11.839640 |
| Park Cost | -8.112157 | 1.149440 | -7.057487 |
| Log-likelihood at zero: | -16440.064829 |
| Log-likelihood at end: | -8883.913854 |
| -2 (LL (zero) - LL (end)): | 15112.301948 |
| Asymptotic rho squared: | 0.459618 |
| Adjusted rho squared: | 0.459253 |

In Table 2, it can be seen that all parameters have signed and have logical signs. The coefficients of three variables in public mode model (travel time, income, and fare) are all negative, which means public mode utility will decrease with the increase of any one of these three variables. The value of $t$-test is significant under confidence level of 95%. The coefficient of the car ownership variable is positive; i.e. higher values of the independent variable will increase the utility of private mode. Variables that were expected to be statistically significant generally are:

- The signs are in the right direction
- The relative values among the independent variables are reasonable.

The goodness-of-fit measure rho-square for the model estimated is 0.459618, It represents a very good fit. The ASC has a negative sign indicating a negative preference of travelling as a passenger in a car with respect to means of public transport. The null hypothesis that all the coefficients are zero is tested by the log-likelihood ratio test ($-2(L (0)-L (B))$) which is $\chi^2$ (chi-square) where test L (C) is the log likelihood of a model with only constants and L (B) is the log likelihood of a model with all variables. It has a degree of freedom equal to K-J+1, where K is the number of model parameters and J is the
number of alternatives in the choice set. The critical $\chi^2$ value with degrees of freedom is equal to 4, and a 0.05 level of significance is 9.488, which is lower than the calculated $\chi^2$ test 14955. Hence, the null hypothesis is rejected at the 95% level, which state that all the coefficients, except the mode-specific constants, are zero. The significance of the model depends on the chi-square test which appear if there is a relationship between the dependent and independent variables. The P-Value is < 0.00001; the result is significant at p < 0.05. The null hypothesis was rejected because there was no difference between the model without independent variables and the model with independent variables.

10. Model Validation
It is the final steps of the modal split model. After calibration of the model is finished, the process of validation is achieved by comparing model estimates with the measured modal split from traffic volumes. Swiss Consultant – De Consult (Consult, 1976) executed a cordon survey around the CBD of Baghdad, i.e. traffic counting at 23 points (street and bridges). The counting points run along the cordon around the CBD and in addition along with a screen line which follows the Tigris River. There are 17 counting points on the CBD cordon and 6 on the screen line. For compatibility reasons, the CBD cordon covers the borders of the district 1 and 2 of the comprehensive development plan. It is observed a good agreement is achieved between mode choice and traffic split results. Figure 3 shows the modal split of the study area in 1976. From the results, it is appeared that public transport is the dominant mode in most parts of the study area.

11. Mode Choice Modelling in the 2014 year
In order to develop the model, socioeconomic characteristics, travel survey data, and traffic data were collected. Household interviews with a questionnaire were developed for this survey. It contains in one part questions related to the demographic structure of the households and in the other part, questions to find out the trips made in one fixed day by all persons living in the household. Population Census data were gathered from the Central Organization for Statistics and Information Technology, it represented an accurate information about the current socioeconomic context of Baghdad. Population Census in 1997 represents the last real census occurred in Iraq. Growth factors based on AL-Khatib and Alami (2012) was depended to estimate socioeconomic characteristics in the 2014 year. TAZ for the 2014 year is different from that of 1976. It included areas where urban development occurred within Mayoralty of Baghdad (MoB); study area was divided into 187 zones.

12. Data Collection
The sample of households was interviewed in the 2014 year with the questionnaire by home interview method, so, the questions are related to personal information of an individual, household
characteristics, information related to the trips in weekdays, trip frequency, and preference of mode. In addition to that, traffic survey using video, photography method was conducted on the main intersections in Baghdad city, eight locations are selected from both Karkh and Rusafa. Traffic count is performed in 1/4/2014 during peak hour. Data are classified according to the type of vehicle and according to the direction. It is noticed that since 2003, a substantial increase in car ownership levels is occurring. According to the data provided by the Central Organization for Statistics and Information Technology as shown in Table (3). The number of vehicles imported during the period 2003 -2006 (1106913 vehicles) and registered under "temporary check" status exceeded the number of registered passenger vehicles and trucks.

Table 3. Number of Vehicle during the Period 1997-2006 (AL-Khatib and Alami, 2010).

| Year  | Saloon | Station car | Field | Bus  | Total  |
|-------|--------|-------------|-------|------|--------|
| 1997  | 673194 | 9015        | 39350 | 51427| 772986 |
| 1998  | 675707 | 9121        | 39569 | 51943| 776340 |
| 1999  | 679698 | 9357        | 39758 | 52598| 781411 |
| 2000  | 685751 | 9572        | 39985 | 53243| 788551 |
| 2001  | 690459 | 9810        | 40147 | 54243| 794659 |
| 2002  | 693700 | 10157       | 40315 | 56034| 800206 |
| 2003  | 701555 | 10426       | 40544 | 57757| 810282 |

| Year  | Passenger Vehicles | Trucks | Total  |
|-------|--------------------|--------|--------|
| 2003  | 99522              | 12595  | 112117 |
| 2004  | 541605             | 104577 | 646182 |
| 2005  | 207696             | 57069  | 264765 |
| 2006  | 59060              | 24789  | 83849  |
| Total | 907883             | 199030 | 1106913|

The growth rate of vehicle ownership in Baghdad has increased since 2003. The statistics show that there was a very sharp and sudden increase in the number of registered vehicles between 2003 and 2006 as shown in Figure 4. In 2004, the increase in the number of imported vehicles was the greatest; it was about 67%.

Figure 4. Number of Cars between the Period 1997-2014.

The growth rate of the number of vehicles is uniformly steady at the beginning and fluctuated from 2003 to 2006. Then, it seems to be steady in the last seven years between 2006 and 2013. This period will be taken and the years before 2006 will be neglected. The maximum growth rate of vehicles was = 3.5% and is used for future forecasting after 2014. To forecast the number of vehicles per zone in 2014, the growth rate =5.5% are adopted. This growth rate was multiplied by the number of cars per the zone of 1997 to calculate the number of cars in 2014. In order to calculate income per zone in 2014, the following calculation is used to predict the income in 2014:

\[
\text{Growth factor} = \frac{\text{Mean of Household Income in 2014}}{\text{Mean of Household Income in 1997}}
\]
From the available information of the Central Organization for Statistics and Information Technology, the mean of household income in 2014 is 1093 $, and the mean of household income in 1997 is 47.5 $; then the growth factor is 23. This growth factor was multiplied by income per household per zone in 1997 to calculate the income in 2014.

13. **Mode Share from Traffic Data Analysis**
The traffic collected data are extracted using visual inspection. Traffic volume was classified for all vehicle types, the following Figures from (5-7) shows traffic composition for some selected area in Baghdad city.

![Traffic Composition Percent](image1.png)

**Figure 5.** Traffic Composition at a) Al-Huriyah Intersection b) Garage Al-Amana Intersection.

![Traffic Composition Percent](image2.png)

**Figure 6.** Traffic Composition at a) Al-Gazila Intersection, at Al-Shulah Intersection.

![Traffic Composition Percent](image3.png)

**Figure 7.** Traffic Composition at Al-Mushtal Intersection during Peak Hour.
14. Modal Split in 2014 Year

After calibrating the logit model, the following Modal split result in 2014 was presented

Valid Cases: 3312

| Parameter  | Estimate  | Std. Err. | t Test  |
|------------|-----------|-----------|---------|
| Fare       | -0.551831 | 0.183778  | -3.002709 |
| IVT        | -0.145559 | 0.010106  | -14.403794 |
| [Income/hh] | -0.000233 | 0.000122  | -1.916149 |
| [Car/hh]   | 0.905099  | 0.062010  | 14.595960 |
| Parking    | -1.362457 | 0.231964  | -5.873578 |
| ASC        | -3.377954 | 0.510737  | -6.613888 |

Maximum likelihood reached at iteration 9

Log-likelihood at zero: -2295.703462
Log-likelihood at end: -1825.901189

-2 (LL(zero) - LL(end)): 939.604545

Asymptotic rho squared: 0.204644
Adjusted rho squared: 0.202031

Figure 8. Shows modal split in 2014.

15. Conclusion

From the mode share result in 2014, it is found that the auto is the most preferred mode, and the makers used this mode for travel between various zones. It is important to shift to public transport mode, by providing comfortable modes, restrict of using auto in congested zones like CBD area, and restrict on use parking, in order to reduce congestion and traffic injuries, and improve air quality.

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