# Trip Generation Rates Using Household Surveys in the State of Qatar

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***Abstract*—Investment in transportation can bring a range of economic, social, and environmental benefits. In order to manage resources effectively and to choose the best decision from a variety of investment options for the transportation projects, transportation model is normally used, moreover it can help in predicting the impact of these transportation project options on traveler's mobility based on future changes in land uses, population, jobs, and other economic factors. Transportation modelling outputs will support in assessing transportation project options and setting the transportation investments priorities. Trip generation is considered the first step in four-stage transport modelling. It estimates the number of trips produced or attracted by households' members over one full day. In the paper, trip generation regression models were developed using household surveys for villas and apartments. The regression models for Villa is (0.357+1.3681X1+2.4914X2) were X1 and X2 and the number of people with driving license and number of active people (employees and students) respectively with an $R^2$ of 0.65 , on the other hand the regression model for the apartment is (0.5323+0.9815X1+2.3961X2) with $R^2$ of 0.54.**

***Index Terms*—trip generation rate, household travel survey, regression models, villa, apartment, census**

## I. Introduction

Over the past few years, the State of Qatar has experienced enormous growth in all aspects of urban life, and as a result of this fast-growing economy, the population of Qatar grew and is expected to continue to increase at a very high rate. Traffic growth and increased cars ownership are two of the corresponding outcomes of this development. According to planning and statistics authority's monthly statistics report [1]. The range of new registered vehicles every month is between 5000 to 6000 vehicles of different types (Private Car, Trailer, Heavy Equipment, Motorcycles, Public transport …etc.). In order to accommodate this growth and reduce the traffic impact of the vehicles on the road network, proper transportation planning must be implemented. Transportation planning is the confluence between many different disciplines. [2] defines the transportation planning as a It is the participatory process done by organizations, agencies and the public, in which demographic characteristics and travel pattern are spatially and temporally examined in order to evaluate current and provide better alternatives for transportation systems. Another definition for the transportation planning is the medium that provides joint interactions between planning design and operation for the services of transportation, this cooperation supports the balance between the efficient mobility form the people while maintaining a healthy and clean environment [3]. In short words transportation planning aims to identify and evaluation future transport needs and works provide proper plans in order to mitigate traffic impact and facilitate transportation for people and goods. The transportation planning processes are (a) Transportation survey, data collection and analysis (b) Use of transportation model (c) Future land use forecasts and alternative policy strategy (d) policy evaluation. The transportation modelling can be desegregated into 4 different processes which are shown in Fig. 1. The main aim of the paper is to identify what are the socio-economic factors that directly affects the trip generation for residential buildings in Qatar i.e. household size, household type, household income, car ownership …etc.

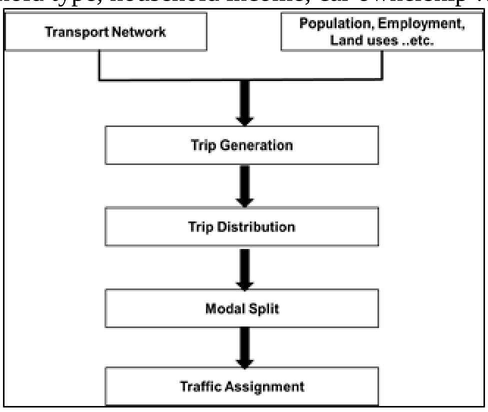


Figure 1. Transport demand modelling 4 stage

According to the latest census in Qatar which was conducted in 2015, almost 84% of residential unit types in Qatar are villas/palace or apartment as depicted in Fig. 2 [4]. Since both villas and apartments are the most dominant residential unit types in Qatar, therefore, it was decided for the purpose of this research, trip generation models to be developed specifically for villas and apartment only. It should be noted that the trip generation models were developed for normal working day only since the individual's travel behaviors is significantly change in weekend.

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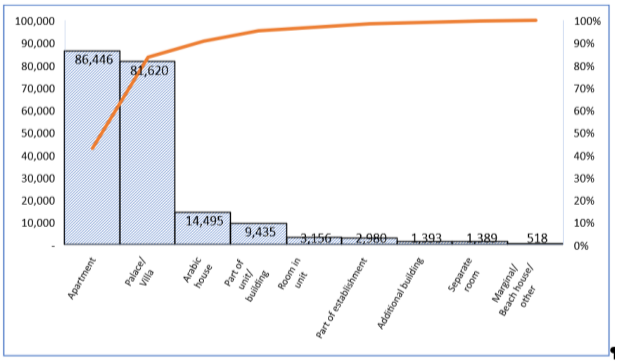


Figure 2. Qatar's Household Types as per 2015 Census (Source: Planning and Statistics Authority, 2018)

## II. Literature Review

Trip generation analysis and model development is one of the four step urban travel analysis and forecasting process recommended by the Bureau of Public Roads (BPR) in the 1950s [5]. The aim of the trip generation process is to predict the number of originating and destined trips for a certain Traffic Analysis Zone (TAZ).

There are many trip generations models and methods that are currently being used on both scales, internationally and locally. The trip generation rates are developed by linking an independent variable or one characteristic of land-use type to the number of trips generated based on a survey. The institute of transportation engineers (ITE) trip generation rates is one of most -internationally- used trip generation. Depending on the land-use type, the manual specifies the independent variable to be used in order to calculate the trip generation, for example for a residential area land-use type the independent variables might be number of bedrooms or total floor area.

Most of the developing countries appreciate the importance of transportation planning and, therefore they adopt at least one or more sophisticated trip generation models to be used [6]. Some countries have adopted international trip generation manuals such as the ITE manual, or they developed their own manuals based on surveys. The approved manual used in the state of Qatar is the Dubai Trip Generation Parking Rate Manual (DTGPRM) 2013. Similar to the ITE, the DTGPRM is based on surveys which were done for multiple land-use types. According to the Ministry of Transportation and Infrastructure report, "Planning and Designing Access to Developments" (MOTI 2009) and TRANS Committee, trip generation in the province of Quebec is based on origin-destination (OD) surveys [7]. In the Ottawa region, which incorporates the city of Gatineau (Quebec) and the city of Ottawa (Ontario), a blended combination of ITE rates and locally estimated rates from an OD survey was used by the TRANS Committee to obtain local rates [7].

Many researchers studied the behavior of transportation and the variables that affect the trip generation. It was observed from the previous studies that, the independent variables that represents the trip generation differs from region to another and sometimes from one community to another in the same country, not only this but in some cases from one household type (palace, villa, apartment, Arabic house, separate rooms …etc.) to another. [8] for example found that the characteristics of trip generation is different between single and multi-person household in different terms including the transport mode in Seoul. Other study showed that the household size is a major variable that influences and should be considered when the trips estimated using household surveys, the study also showed that the income does not influence the trip generation especially for single-person household [9]. [10] concluded that the trip generation depends on car ownership, socio-economic factors (Income) and the type of land-zone. [11] showed that the household size, employed persons, students, members above 12 and number of driving licenses within the household are the independent variables that influences the homebased trips in Nigeria. Furthermore, a study was conducted to predict trip generation for a large housing project in Indonesia and found that the independent variables that affected the trip generation are the household size, employees and students withing the household this is in addition to the vehicle ownership [12]. [13] Presented a study that found household size, car ownership and income level were the best factors that can describe the number of generated trips. [14] Stated that trip production model mainly depends on family size, gender, the number of workers and the number of students in the family.

## III. Methods

As mentioned earlier, trip generation models were developed for the main residential unit types (Villas and Apartment) in Qatar using household travel interviews (HHTI) which was conducted by Ministry of Transport and Communication (MOTC, 2018) between 2017-2018. HHTI serve to understand the travelling patterns for individuals within households. They enable the determination of the sequences of trips during rigid start time of activities (work, school) or flexible trips (shopping, entertainment, and leisure). It can be also serve to understand the selection of modes of transportation and estimate modal split within trips and the mix of trips in a tour. In this study, HHTI was analyzed using regression analysis to reveal the correlation between socioeconomic characteristics of the household unit types and how this can be used to predict the number of trips per normal working day.

### A. Data Collection

The raw data of HHTI was collected from MOTC, which has been conducted during the years 2017-2018 as part of Transportation Master Plan for Qatar (TMPQ) project. The HHTI surveys aimed to collect travel data from a representative selection of households across Qatar, capturing household characteristics including vehicle details, person details, and a location-driven activity diary for each member of the household aged over five. The interview form used for HHTI is obtained from MOTC with full description of its methodology and sampling procedure. However, due confidentiality agreement in obtaining the data from MOTC, the HHTI survey form and raw data cannot be published in this paper. This has no impact on the data analysis and any calculation presented in subsequent sections.

By understanding the travel patterns for individuals within households from HHTI, the trip generation models for households by type were estimated. The sampling strategy for the Qatar HHTI surveys was based on a stratified probability sample of households. The procedures used to derive the detailed sample frame enabled the overall target sample for two levels (namely, household residential type and by Nationality Qatari and non-Qatari households) to be separately specified based on the Qatar census 2015. Data refinement and checking procedure have been applied to remove incomplete HHTI and to include only HHTI conducted during normal working day in Qatar (Sunday to Thursday) as illustrated in Table I which provide the sample size and rate compared to the overall Qatar's Residential Census by type. The HHTI surveys conducted in weekend were not considered in this sample for the purpose of developing trip generation model.

TABLE I. HHTI SAMPLE SPATIAL DISTRIBUTION BASED ON RESIDENTIAL TYPE COMPARED TO 2015 CENSUS

| Residential Unit Type | Sample Size | Census 2015 | % Sample |
|---|---|---|---|
| Apartment | 4,153 | 86,446 | 4.80% |
| Villa | 2,982 | 81,620 | 3.65% |
| Total | 7,135 | 168,066 | 4.25% |

Table II shows some typical household travel interview sampling rates in recent largescale household interview surveys undertaken for the development of demand models covering car ownership, trip/activity. The sample percentage collected for apartment and villas was 4.25 % across all residential unit type and ranges between 3.65% to 4.80% depending on the type of residential unit.

Based on Table I, it can be seen clearly that the overall HHTI sample percentage collected in Qatar with almost 4.25% is more than the percentage sample used in any other studies presented in Table II.

TABLE II: WORLDWIDE EXAMPLES FOR HOUSEHOLD TRAVEL INTERVIEW SAMPLING RATES

| Location | Number of Surveys | Number of Households | Percentage Sample |
|---|---|---|---|
| New York | 18,965 | 7,783,415 | 0.24% |
| Chicago | 14,315 | 3,761,312 | 0.38% |
| Atlanta | 10,278 | 2,065,336 | 0.50% |
| San Francisco Bay | 7,896 | 2,785,948 | 0.28% |
| California HTS | 42,430 | 12,577,498 | 0.34% |
| London | 40,000 | 3,266,170 | 1.22% |
| West Midlands (UK) | 17,000 | 2,329,000 | 0.73% |
| Singapore | 10,000 | 1,174,500 | 0.85% |
| Sydney | 14,636 | 1,689,000 | 0.87% |
| Leicester (UK) | 1,880 | 111,148 | 1.69% |
| Abu Dhabi - 2009 | 3,288 | 265,890 | 1.24% |
| Abu Dhabi - 2015 | 6,050 | 319,000 | 1.90% |

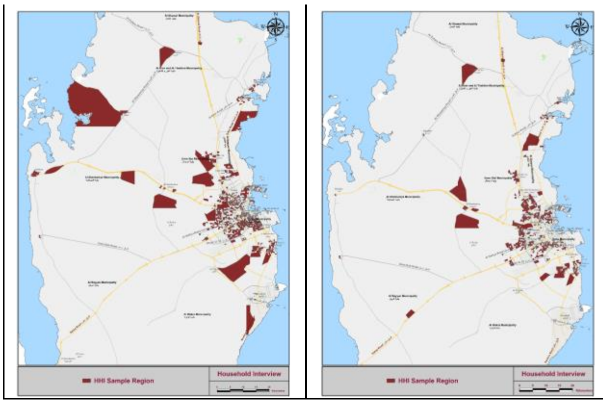

Figure 3. Sample spatial distribution for Qatari and Non-Qatari household

To ensure geographic representation, the sample adopted a geographic stratification scheme, which ensures adequate representation of households throughout the study area, shows the sample spatial distribution across Qatar census blocks as shown in Fig. 3. The HHTI survey was administered using a tablet-based application. The form contains three basic sections: household characteristics; personal characteristics; and a detailed travel and activity diary for each household member over the age of five. The primary application of the HHTI data in this study was to estimate trip generation rates for various types of residential unit across Qatar. A secondary application of the HHTI data relates to deriving the correlation between HH characteristics information and the travel characteristics and patterns encountered in Qatar. It should be noted that the HHTI was conducted by face-to-face interview using a tablet-based app, which has several advantages. Adopting a Computer-Assisted Personal Interviewing (CAPI) approach enables huge advantages in terms of data quality and transparency and allows for an audit trail. Detailed quality management was applied at each stage of the travel survey study rather than simply at the point of data collection and reporting. During the HHTI survey, logic checks were implemented in the code which alerted the interviewer to illogical choices which may have been made by error or by will. The built-in logic checks minimize the requirement for post survey logic checks which will further reduce the processing time and ensure prompt delivery of data. However, in order to prepare the HHTI for the statistical analysis in this research, numbers of checks have been conducted including but not limited to the following:

Checking the total number of persons in HH with persons characteristics

a) Matching the age of HH persons with the purpose of trip such as education/school can be only for persons less than 18 years old.
b) Removing HHTI data where income is reported as confidential.
c) Checking the number of persons with driving licenses and persons age (0-15 years could not be a driver).

Checking the sequence of trips and ensure the place of starting trip match the location of previous trip while classifying trips to HBT or NHBT

Based on the described checking procedure, the remaining sample size cleaned and include all the information required for statistical analysis is 7,135 out of 11,286 HHTI sample. The following data were extracted from each household travel interview to be used in this research:

1) Household characteristics.
   - Household Property Type namely (Apartment, Arabic House, Compound Villa, Palace, Part of Unit/Building, Room (In Unit or Separate), Standalone Villa)
   - Household Size: Total number of people resident in household unit.
   - Household Nationality.
   - Household income band.
   - Car ownership (number of motorized vehicles);
   - Number of Employed Persons.
   - Number of Students.
   - Number of active persons (Number of Students+ Number of Employed Persons);
   - No. of Persons with Driving License
2) Travel Diaries.
   - Number of trips per day (regardless of travel mode used)
   - Type of place for origin and destination of trip - e.g. home, work, school (Split to Home-Based Trip (HBT) and Non-Home-Based Trip (NHBT)
   - Start and End Time of Trip
   - Mode of travelled used to reach place

The travel diary data includes the HBT and NHBT for a typical working day along with the time series of these trips. Furthermore, the trip specific information on mode, destination, travel time, travel cost, and activity undertaken is all linked to the corresponding household records. This enables analyses by household to be undertaken and the differences in travel characteristics between different categories of households to be identified. However, this subsequent analysis can be done in the subsequent stages of the four-stage transport model presented in Figure 1 but not included in this paper.

*B. Statistical Analysis Approach*

The following steps described below represent the statistical approach used in this research to develop trip generation model:

- Conduct descriptive statistics for HHIT (Mean, Mode, Standard Deviation, ..etc)
- Draw scaterred plots and whisker boxes for all variables to understand the correlation between the number of generated trips per household residential unit and socio-economic variables.
- Test the normality of the collected sample and decide if parametric test can be used to develop trip generation model based on set of socio-economic characteristics of the household to estimate number of trips per residential unit type.
- Identify and remove outliers: Grubbs's test is used based on the assumption of normality. Grubbs's test detects one outlier at a time. This outlier is expunged from the dataset and the test is iterated until no outliers are detected.
- Generate independent variables and dependent variable: by analyzing the descriptive statistics and then conduct correlation test. The dependent variable in this study was set as the daily trips of household and the possible independent variables are described in household characteristics,
- Check the relationships among the independent variables for multi-co linearity: If the correlation coefficient between two independent variables is high, then one variable has the larger correlation coefficient with the dependent variable will be included in the regression models but not both the variables.
- Model estimation: The multiple linear regression method was chosen to estimate number of daily trips per household unit which consists of creating the equations in which the trips are related to household socio-economic characteristics (defined in independent variables). For this analysis, using the multiple linear regression approach, it is presumed that the relationships formed for the model are constant and will remain the same in the future, and so where land-use and socio-economic variables can be predicted; future household travel can be estimated.
- The trip generation equation is formed as follows:

$$TGR = \beta\beta o + \beta 1 X1 + \beta 2X2 + \beta 3X3 + \cdots + \beta n X n$$

- State the null hypothesis and set the confidence level to be 0.95. Hypothesis testing must be needed to determine the significance of the individual coefficients obtained from the regression analysis based on the selected confidence level 0.95. The statements of hypothesis to test the significance of a regression coefficient for each variable as follows:

$$Ho: \beta i = 0$$

H1: βi ≠ 0

where β: regression coefficient

Minitab was used as statistical software to carry out the above described statistical analysis.

### *C. Assumptions*

As mentioned earlier, this study was conducted based on the HHTI acquired from MOTC. The following points are repressing the study assumptions and limitations:

a) The trip generation representing the typical working days only
b) The sample size has been determined by MOTC and accordingly the HHTI survey was performed according to pre-defined sampling procedure. It has been assumed the HHIT sample size collected by MOTC is adequate and it has been compared to other HHIT surveys conducted worldwide for validation purposes only.

The literature review conducted to decide the factors affecting trip generation by household socio-economic characteristics. Accordingly, the relevant data/variables have been extracted from HHIT.

## IV. Data Analysis Results

Different potential socio-economic characteristics of house units were examined. The aim is to predict the daily generated trips number from each (villa unit and apartment unit) during normal working days. Based on literature review outcome and scattered and whisker plots, the following are chosen as a candidate terms to predict total trips.

- Household size (HH_size): number of residents inside the unit
- Income level per housing unit (HH_income)
- Vehicle ownership
- Nationality: Qataris Vs Non-Qataris
- No. of persons with driving license
- No. of Active persons: Total No. of Employees and students per Housing unit

### *A. Descriptive Analysis*

Summary of the main descriptive statistics for above mentioned variables is presented in Table III. It can be seen clearly that the mean of villas residential unit has higher income, household size (number of persons lives in the same unit), number of employed persons, number of students and even number of persons with driving license. According, the mean for number of daily trips per villa is almost 8.473 trips which is significantly higher the apartment of 5.731 trips. In addition, the daily trips median for villa is 6 trips while is only 4 trips for apartment. However, the standard error and variance for number of daily trips for villas are higher than the one for apartment.

### *B. Normality Test for Total Trips*

Normality test for number of daily trips was conducted for both villas and apartments. The hypothesis of Normality test is set as the following:

H0: The sample dataset is normally distributed
H1: The sample dataset is not normally distributed

Fig. 4 shows that null hypotheses is rejected at significance level α = 0.05 for sample datasets for both villa and apartment residential unit type. [15] Mentioned that with large enough sample sizes (> 30 or 40), the violation of the normality assumption should not cause major problems; this implies that we can use parametric procedures even when the data are not normally distributed [16]. Since, the samples used for this study consist more than seven thousands of observations; we can ignore the distribution of the data. According to the central limit theorem, (a) if the sample data are approximately normal then the sampling distribution too will be normal; (b) in large samples (> 30 or 40), the sampling distribution tends to be normal, regardless of the shape of the data (Elliott AC & Woodward WA, 2007); and (c) means of random samples from any distribution will themselves have normal distribution.

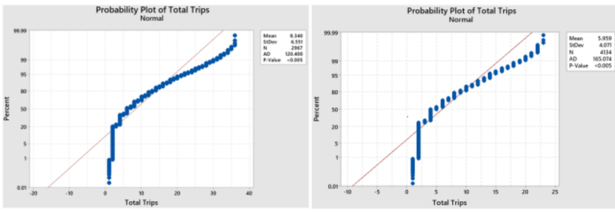


Figure 4. Normality test for total trips generated in working days-villas & apartments

### *C. Outliers Test*

Grubbs's test was conducted using Minitab to identify outliers. Grubbs test was repeatedly conducted to remove all outliers until no outliers are found since only one outlier can be found at single test. All outliers were removed from the dataset. The hypothesis of Grubbs test is set as the following:

H0: No outliers in the data set
H1: One outlier in the data set

TABLE III. Descriptive Analysis for HHTI for Villa and Apartment (a)

| Villa/ apartment | HH Income | HH Size | HH Vehicle Ownership | HH No. of Employed Persons | No. of Students | No. of P. with Driving License | Number of Daily Trips |
|---|---|---|---|---|---|---|---|
| Mean | 31,491 | 4.748 | 2.047 | 1.411 | 1.008 | 1.474 | 8.473 |
| | 11,133 | 2.879 | 0.983 | 1.238 | 0.525 | 0.956 | 5.731 |
| Standard Error | 578 | 0.054 | 0.029 | 0.016 | 0.026 | 0.018 | 0.126 |
| | 91 | 0.03 | 0.012 | 0.009 | 0.017 | 0.012 | 0.078 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Median | 17,500 | 4 | 2 | 1 | 0 | 1 | 6 |
| | 12,500 | 3 | 1 | 1 | 0 | 1 | 4 |
| Mode | 27,500 | 4 | 1 | 1 | 0 | 1 | 2 |
| | 12,500 | 1 | 1 | 1 | 0 | 1 | 2 |
| Standard Deviation | 31,589 | 2.963 | 1.578 | 0.863 | 1.417 | 0.995 | 6.855 |
| | 4,989 | 1.621 | 0.672 | 0.514 | 0.934 | 0.669 | 4.274 |
| Sample Variance | 997,857,944 | 8.778 | 2.49 | 0.745 | 2.008 | 0.989 | 46.997 |
| | 24,893,541 | 2.626 | 0.451 | 0.264 | 0.873 | 0.448 | 18.27 |
| Kurtosis | 4.87 | 0.753 | 3.856 | 5.416 | 2.343 | 3.105 | 3.181 |
| | -0.92 | 1.492 | 0.605 | 4.594 | 4.295 | 0.703 | 5.555 |
| Skewness | 2.1 | 0.927 | 1.615 | 1.802 | 1.547 | 1.405 | 1.612 |
| | -0.26 | 0.75 | 0.432 | 1.492 | 2.02 | 0.44 | 1.881 |
| Range | 149,500 | 19 | 12 | 8 | 10 | 7 | 48 |
| | 17,000 | 15 | 4 | 6 | 6 | 4 | 41 |
| Minimum | 500 | 1 | 0 | 0 | 0 | 0 | 1 |
| | 500 | 1 | 0 | 0 | 0 | 0 | 1 |
| Maximum | 150,000 | 20 | 12 | 8 | 10 | 7 | 49 |
| | 17,500 | 16 | 4 | 6 | 6 | 4 | 42 |
| Confidence Level(95.0%) | 1,134 | 0.106 | 0.0567 | 0.031 | 0.0509 | 0.0357 | 0.2462 |
| | 179 | 0.058 | 0.0241 | 0.0185 | 0.0335 | 0.024 | 0.1535 |

Fig. 5 shows that the final dataset satisfies the null hypothesis for Grubbs test as the p-value is more than 0.05 which implies that the fail to reject the null hypothesis at significance level $\alpha = 0.05$. The subsequent statistical analysis and regression model estimation was carried out based on the dataset after removing outliers.

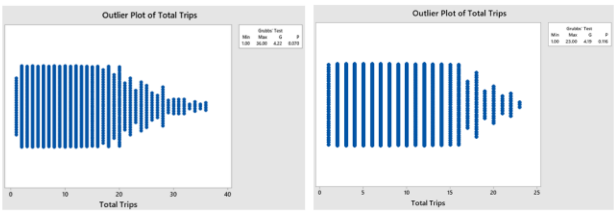


Figure 5. No outliers at 5% level of significance for villas and apartments respectively

## A. Correlation Test

Correlation test was conducted between socioeconomic characteristics (Independent variables) and number of daily trips (Dependent Variable) generated for both villas and apartment unit types. The hypothesis of correlation test is set as the following:

H0: The number of trips is not associated/correlated with independent variable

H1: The number of trips is associated/correlated with independent variable

Table IV and Table V illustrate the correlation test results for Villa and Apartment unit types, respectively. It can be concluded the following:

- Since p-value is less than 0.05, then the null hypothesis is rejected for correlation between number of daily trips household (HH) socio-economic characteristics except for nationality which found that there is no significant relationship with number of daily trips since variables p-value is more than 0.05. Therefore, income, household size, vehicle ownership, number of persons with driving license and number of active persons in household found to be associated with number of household daily trips.
- HH income and nationality variables are found to have very low correlation with the HH number of daily trips.
- For Both villa and apartment, the No. of active people, No. of persons with driving license and household size showed a high correlation with total trip generated. The multicollinearity is then checked next to avoid selecting tow highly correlated predictors.

All independent variables have a positive linear relationship with HH number of daily trips.

TABLE IV. CORRELATION COEFFICIENT AND P-VALUE FOR VILLA UNIT TYPE

| Independent Variable | Tot. Trips | | |
|---|---|---|---|
| | Correlation Coefficient (R) | P value | Ho |
| HH Income | 0.345 | <0.001 | reject |
| HH size | 0.656 | <0.001 | reject |
| HH Vehicle ownership | 0.432 | <0.001 | reject |
| HH Nationality | 0.284 | <0.001 | reject |
| No. of Persons with Driving License in HH | 0.579 | <0.001 | reject |
| No of active people in HH | 0.788 | <0.001 | reject |

TABLE V. CORRELATION AND P-VALUE FOR APARTMENT UNIT TYPE

| Independent Variable | Tot. Trips | | Ho |
|---|---|---|---|
| | Correlation Coefficient (R) | P value | |
| HH Income | 0.146 | <0.001 | reject |
| HH size | 0.563 | <0.001 | reject |
| HH Vehicle ownership | 0.331 | <0.001 | reject |
| HH Nationality | -0.015 | 0.333 | Fail to reject |
| No. of Persons with Driving License in HH | 0.436 | <0.001 | reject |
| No of active people in HH | 0.717 | <0.001 | reject |

### *B. Correlation Matrices for Multicollinearity Test*

Table VI and Table VII summarize the multicollinearity test Results as form of correlation matrix among independent variables. For any independent variables pair with high correlation is removed. For instance, HH number of active persons was found with high correlation with HH size, therefore HH size independent variable was removed and HH number of active persons during regression analysis kept in regression analysis. Similarly, HH number of persons with driving license was found highly correlated with HH car ownership, therefore car ownership was removed during regression analysis HH no. of persons with driving license variable was kept in regression analysis.

### *C. Regression Model Results*

The remaining sample of 2967 for villa and 4134 for apartment after removing outliers were used for multiple linear regression analysis. Multiple linear regression analysis was decided based on the review of scatter plots of all independent variables with the HH number of daily trips. Regression analysis was iterated many times with many possibilities for independent variables while comparing the statistical results such as R2, t-test, p-value, f-test, VIF and mallows. After each iteration, the regression model assessed based on statistical test till the most suitable model is achieved.

For villa unit type, the final regression equation is

$$HH\ Number\ of\ Daily\ trips = 0.357 + 1.3681\ No.of\ persons\ with\ driving\ license + 2.4914\ No.of\ active\ persons$$

For apartment unit type, the final regression equation is

$$HH\ Number\ of\ Daily\ trips = 0.5323 + 0.9815\ No.of\ persons\ with\ driving\ license + 2.3961\ No.of\ active\ persons$$

It can be noticed that the effect of independent variables on HH number of daily trips is slightly higher for villa which implies that an increase of one active person with driving license lives in Villa unit type will have almost 0.3 trips more than the similar person lives in apartment. Although the difference looks low, however this makes a huge difference if applied on large scale development with thousands of residential units. For example, if 1000 apartment replaced by 1000 villa then almost 300 more trips will be generated, and probably new road access or additional public transport service will be required.

#### *a. T-Test*

H0: coefficient = 0,
H1: coefficient ≠ 0

As shown in Table VIII and Table IX the T-value for all constants and coefficients is more than the critical t-value, these values are statically significant at the 99.5% level thus the null hypothesis is rejected, and coefficients have a significant positive effect on total trips generated.

#### *b. Variance inflation factor (VIF)*

The values of all explanatory variables used in the regression model are presented in the table above, and all are less than 5. Therefore, no multicollinearity effect or over-fitting phenomena.

TABLE VI. MULTICOLLINEARITY TEST RESULTS: CORRELATION COEFFICIENT FOR INDEPENDENT VARIABLES FOR VILLA UNIT TYPE

| *Correlation Coeeficient* | *HH- income* | HH_size | HH Vehicle ownership | HH Nationality | HH No. of Persons with Driving License | HH No of active people |
|---|---|---|---|---|---|---|
| *HH-income* | X | | | | | |
| HH_size | 0.491 | X | | | | |
| HH Vehicle ownership | 0.626 | 0.621 | X | | | |
| HH Nationality | 0.508 | 0.496 | 0.512 | X | | |
| HH No. of Persons with Driving License | 0.453 | 0.550 | 0.643 | 0.349 | X | |
| HH No of active people | 0.353 | 0.706 | 0.424 | 0.268 | 0.553 | X |

TABLE VII. MULTICOLLINEARITY TEST RESULTS: CORRELATION COEFFICIENT FOR INDEPENDENT VARIABLES FOR VILLA UNIT TYPE

| *Correlation Coeeficient* | *HH- income* | HH_size | HH Vehicle ownership | HH Nationality | HH No. of Persons with Driving License | HH No of active people |
|---|---|---|---|---|---|---|
| *HH-income* | X | | | | | |
| HH_size | 0.132 | X | | | | |
| HH Vehicle ownership | 0.264 | 0.425 | X | | | |
| HH Nationality | 0.133 | 0.017 | 0.034 | X | | |
| HH No. of Persons with Driving License | 0.257 | 0.395 | 0.692 | 0.016 | X | |
| HH No of active people | 0.133 | 0.682 | 0.347 | -0.007 | 0.414 | X |

TABLE VIII. REGRESSION ANALYSIS RESULTS FOR VILLA UNIT TYPE

| intercept and variables | Coefficient | T-value | p-value | F-value | p-value | VIF |
|---|---|---|---|---|---|---|
| intercept | 0.357 | 2.64 | 0.008 | | | |
| No. of Persons with Driving Lic | 1.3681 | 15.8 | <0.001 | 249.67 | <0.001 | 1.44 |
| No of active people | 2.4914 | 51.8 | <0.001 | 2683.53 | <0.001 | 1.44 |
| R squared | | | 65.1% | | | |
| R2 pred | | | | | | |
| Regression F-value | | | 2764.2 | | | |

TABLE IX. REGRESSION ANALYSIS RESULTS FOR APARTMENT UNIT TYPE

| intercept and variables | Coefficient | T-value | p-value | F-value | p-value | VIF |
|---|---|---|---|---|---|---|
| intercept | 0.5323 | 5.77 | <0.001 | | | |
| No. of Persons with Driving Lic | 0.9815 | 14.43 | <0.001 | 208.26 | <0.001 | 1.21 |
| No of active people | 2.3961 | 55.77 | <0.001 | 3109.79 | <0.001 | 1.21 |
| R squared | | | 53.79% | | | |
| R2 pred | | | | | | |
| Regression F-value | | | 2404.73 | | | |

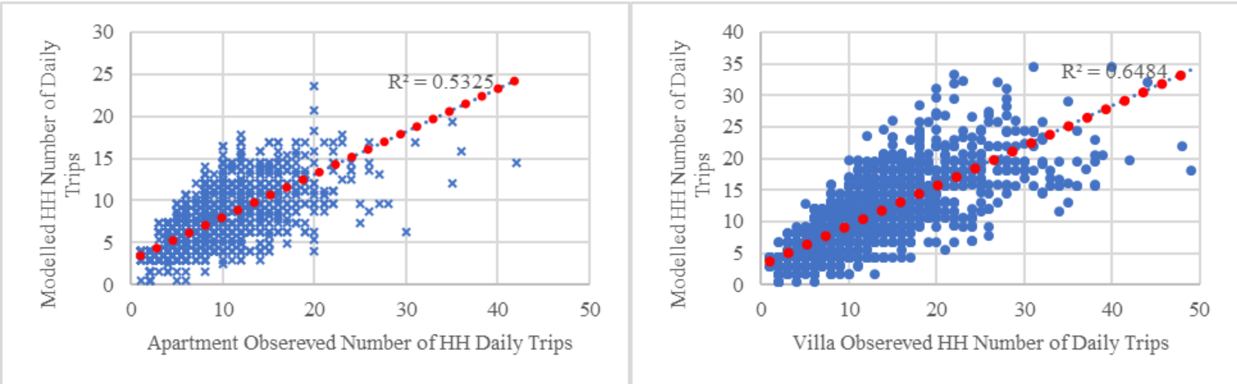


Figure 6. No outliers at 5% level of significance for villas and apartments respectively

*c. Goodness of fitness: R-squared*

The R-squared value for Villa and apartment regression model is 0.65 and 0.538 respectively this indicate that independent variables chosen explain 65% and 53.8% of the variation of total trips generated and is considered to be reasonable compared to similar models developed in other studies as explained in the literature review

*d. Overall model significance F-test*

H0: all coefficient = 0,

H1: all coefficient ≠ 0

As shown in Table VIII and Table IX, the F-value for regression model is in thousands for both villas and apartments with P-value <0.001 thus the null hypotheses is rejected and the chosen socioeconomic variable jointly predict the total trips generated

*e. Observed versus modelled*

Fig. 6 a scatter-plot diagram for observed and modelled trip generation for both villa and apartment sample.

## V. CONCLUSION

As summary, this paper showed detailed analysis for the household survey data that was obtained from MOTC in the state of Qatar. correlation between dependent (Trips) with independent (Household size, type, income, members with driving license, active members, vehicle ownership) and independent with independent variables was tested, then multiple linear regression models were developed, however, it was found that the number of active people (students and employees) and the number of persons with driving licenses, are the main independent variables that influences the trip generation for the analyzed residential units, these factors are found to be in accordance with multiple research papers which were done in other countries and regions although having different traffic behavior than Qatar. The regression model for villas and apartments are:

For villa unit type, the regression equation is

$$\begin{aligned} &\textit{HH Number of Daily trips} \\ &\quad = 0.357 + 1.3681\ \textit{No. of persons with driving license} \\ &\quad + 2.4914\ \textit{No. of active persons} \end{aligned}$$

For apartment unit type, the regression equation is

$$\begin{aligned} &\textit{HH Number of Daily trips} \\ &\quad = 0.5323 + 0.9815\ \textit{No. of persons with driving license} \\ &\quad + 2.3961\ \textit{No. of active persons} \end{aligned}$$

64% and 54% of the variability of HH daily trips are explained in the developed model. However, the uncertainty of the model can be related to inaccuracy of reported income which has found to be one of most important variables in similar models in other countries. Probably, the interviewed household member did not reveal correctly their income level. Once future surveys conducted with more accurate capture of HH income, then update of analysis will be required.

One of the limitations was the un-availability of the building floor areas and the available number of rooms within each type of the analyzed units, obtaining these data can result in stronger regression models, these regression models can be compared with the ITE and DTGPRM. Future work can also include developing multilinear regression models for other residential types and by using different classifications (trip purpose, income …. etc.

## CONFLICT OF INTEREST

The authors declare no conflict of interest

## AUTHOR CONTRIBUTIONS

KA conducted the research and literature review in addition to part of the data analysis; AM collected the data and proposed analysis methodologies; ME continued with the data analysis. KA, AM & ME wrote their part in the paper;...; PC reviewed the paper, proposed some modifications, and approved the final version.

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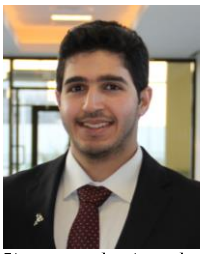

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