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Developing a Trip Generation Model for South Tripoli Using Linear Regression Analysis: A Case Study of Residential Travel Behavi

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Abstract

South Tripoli has experienced substantial demographic, economic, and spatial transformations over the past decade, leading to significant increases in travel demand and pressure on its urban road network. Efficient transportation planning requires accurate estimation of household-level trip production, yet cities in Libya continue to lack locally calibrated trip generation models derived from empirical socio-economic data.

This study develops a trip generation model for South Tripoli using multiple linear regression analysis, relying on primary household survey data collected from residential zones in the southern suburban districts. A stratified random sampling technique was implemented across defined Traffic Analysis Zones (TAZs), yielding a final sample of 430 households. Household socio-economic characteristics—including family size, number of workers, income levels, vehicle ownership, age structure, and licensed drivers—were evaluated as predictors of total trip production and specific trip purposes. Results indicate that the overall trip generation model achieves a strong explanatory power, with an R^2 of 0.44, suggesting that approximately 44% of the variance in household trip production is explained by the socio-economic variables. The most influential predictors were: number of workers, number of licensed drivers, household size, and number of qualified/educated persons. These findings align with earlier studies in both developed and developing contexts, where economic activity and mobility capacity strongly correlate with trip frequency.

The study provides a locally calibrated and statistically validated framework for urban planners in Tripoli, enabling more reliable forecasting of travel demand and supporting future infrastructure investment decisions. It also recommends building nonlinear and machine learning–based extensions to improve predictive accuracy in evolving Libyan citie.

Keywords: Trip generation; South Tripoli; linear regression; household travel behavior; transportation planning; socio-economic variables; Traffic Analysis Zones (TAZs); Libya.

المستخلص

شهدت منطقة جنوب طرابلس خلال العقد الماضي تحولات ديموغرافية واقتصادية ومكانية كبيرة، مما أدى إلى زيادة كبيرة في الطلب على السفر وضغط على شبكة الطرق الحضرية. يتطلب التخطيط الفعال للنقل تقديرًا دقيقًا لإنتاج الرحلات على مستوى الأسر، إلا أن المدن في ليبيا لا تزال تفتقر إلى نماذج توليد رحلات محلية مُعايرة تعتمد على بيانات اجتماعية واقتصادية تجريبية.

تقوم هذه الدراسة بتطوير نموذج لتوليد الرحلات في جنوب طرابلس باستخدام تحليل الانحدار الخطي المتعدد، اعتمادًا على بيانات استبيانات أولية للأسر جُمعت من مناطق سكنية في الضواحي الجنوبية للمدينة. وقد تم تنفيذ تقنية أخذ عينات عشوائية طبقية عبر مناطق تحليل حركة المرور المحددة(TAZs) ، مما أسفر عن عينة نهائية تتكون من 430 أسرة. وتم تقييم الخصائص الاجتماعية والاقتصادية للأسر بما في ذلك حجم الأسرة، عدد العمال، مستويات الدخل، ملكية المركبات، التركيبة العمرية، وعدد السائقين المرخصين كمتغيرات متنبئة بإجمالي إنتاج الرحلات والأغراض المحددة للرحلات.

تشير النتائج إلى أن نموذج توليد الرحلات العام يتمتع بقدرة تفسيرية قوية، حيث بلغ معامل التحديد0.44 (R^2) ، مما يشير إلى أن حوالي 44% من التباين في إنتاج الرحلات الأسرية يمكن تفسيره بواسطة المتغيرات الاجتماعية والاقتصادية. وكانت أهم المتغيرات المؤثرة هي: عدد العمال، عدد السائقين المرخصين، حجم الأسرة، وعدد الأشخاص المؤهلين/المتعلمين. تتماشى هذه النتائج مع الدراسات السابقة في السياقات المتقدمة والنامية، حيث يرتبط النشاط الاقتصادي وقدرة التنقل ارتباطًا قويًا بتكرار الرحلات.

توفر الدراسة إطارًا محليًا مُعايرًا ومُثبتًا إحصائيًا لمخططي المدن في طرابلس، مما يمكّن من توقعات أكثر موثوقية للطلب على السفر ويدعم قرارات الاستثمار المستقبلية في البنية التحتية. كما توصي الدراسة بتطوير امتدادات غير خطية وباستخدام تقنيات التعلم الآلي لتحسين دقة التنبؤ في المدن الليبية المتطورة..

1. Introduction

Transportation systems are essential components of urban development, influencing accessibility, mobility, economic productivity, and social well-being. In rapidly growing urban regions, such as South Tripoli, travel demand has increased significantly due to demographic expansion, rising household vehicle ownership, and shifts in land-use structure. These changes have created pressures on the existing transportation network, resulting in congestion, travel delays, and reduced mobility efficiency.

Accurate estimation of travel demand, especially at the household level, forms the first and most crucial stage of the four-step transportation planning process: **trip generation, trip distribution, mode choice, and network assignment**. Trip generation defines the quantity of trips produced and attracted by zones or households, and is therefore fundamental for forecasting future traffic flows and planning roadway capacity, public transport services, and land-use allocations.

Despite its importance, Libyan cities—including **Tripoli—lack empirically derived and locally** calibrated trip generation models, relying instead on generalized ratios or outdated references from foreign contexts. This gap reduces the accuracy of transportation impact assessments, corridor traffic studies, and long-term strategic plans. The absence of structured public transit systems and the dominance of private car usage further increase the need for context-specific trip generation modeling.

South Tripoli, consisting of mixed residential zones, peri-urban settlements, and expanding suburban neighborhoods, represents an ideal case study for developing a household-based trip generation model using modern statistical techniques.

3.1- Problem Statement

South Tripoli has experienced a notable increase in vehicle ownership due to improvements in household income, reduced import taxes on automobiles, and the absence of regulated public transportation services. When combined with population growth and spatial expansion, this pattern has resulted in:

- Higher rates of household trip production
- Increased dependency on private cars
- Rising peak-hour congestion
- Lack of adequate road infrastructure and public transport alternatives

Transportation authorities currently lack **reliable modeling tools** to quantify and forecast household travel demand based on socio-economic characteristics. Existing planning decisions are therefore based on incomplete assumptions, which affects the efficiency of infrastructure investments, land-use development policies, and mobility strategies.

Thus, the central research problem is:

There is no locally calibrated mathematical model that predicts household trip generation in South Tripoli based on its unique socio-economic and demographic characteristics.

4.1_ Research Aim

The main aim of this study is:

To develop a statistically validated linear regression model capable of predicting household trip generation in South Tripoli based on socio-economic, demographic, and mobility-related variables.

5.1_ Research Objectives

To achieve the main aim, the study pursues the following specific objectives:

1. **Identify and analyze household socio-economic variables** that influence trip production in South Tripoli.
2. **Collect primary household travel data** through structured surveys across multiple Traffic Analysis Zones (TAZs).
3. **Apply simple and multiple linear regression techniques** to develop predictive models for total trips and purpose-specific trips.
4. **Evaluate model reliability** using statistical indicators such as R^2, F-test, t-tests, significance levels, and multicollinearity diagnostics (VIF).
5. **Calibrate and validate the model** using field data to ensure its applicability in real planning scenarios.
6. **Develop a transferable modeling framework** that can be replicated in other districts of Tripoli and other Libyan cities.

6.1_ Significance of the Study

This study contributes to transportation planning in Libya at several levels:

7.1_ Scientific contribution

- Provides the first empirically calibrated trip generation model for South Tripoli.
- Expands local research in transportation engineering, which remains limited in Libya.
- Enhances understanding of how household features—income, workers, vehicles, age groups—shape travel behavior.

8.1_ Planning contribution

- Enables more accurate traffic forecasts for future infrastructure design.
- Supports road capacity planning, intersection upgrades, and suburban mobility strategies.
- Helps policymakers assess impacts of new residential developments.

9.1_ Practical contribution

- Offers a tool for transport consultants, urban planners, and public agencies.
- Facilitates transportation impact studies (TIS) and urban expansion planning.
- Provides a foundational database of household travel patterns in South Tripoli.

10.1_ Scope of the Study

The study covers:

- **Geographical scope:** Residential districts located in South Tripoli.
- **Population scope:** Households across stratified TAZs.

- **Data scope:** Daily trips produced by households for various purposes (work, education, shopping, social, recreational).
- **Modeling scope:** Linear regression techniques only (simple and multiple regression).

The study does **not** include:

- Trip attraction modeling
- Mode choice modeling
- Freight or commercial trips
- Non-motorized trips in detailed form

11.1_ Structure of the Paper

This research paper is organized into the following major sections:

1. **Introduction**
2. **Literature Review**
3. **Methodology**
4. **Field Survey and Data Collection**
5. **Statistical Analysis and Model Development**
6. **Results and Discussion**
7. **Conclusion and Recommendations**

12.1_LITERATURE REVIEW

12.1.1_Overview of Trip Generation Studies

Trip generation modeling is a fundamental step in the classical four-stage transportation planning process. It defines the total number of trips produced and attracted by a zone or household, as influenced by socio-economic, demographic, and land-use factors. Multiple scholars have demonstrated the importance of household characteristics—such as income, number of workers, household size, and car ownership—in predicting daily mobility behavior (Hutchinson, 1974; Meyer & Miller, 1986).

In developing countries, where public transport is often limited and private car dependency is high, socio-economic variables tend to exert stronger influence on trip production (Maunder, 1981). Studies in India, Jamaica, and various Middle Eastern cities have confirmed that household composition and economic status are key determinants of mobility patterns.

12.1.2_Trip Generation Approaches

Two major methodological approaches dominate the literature:

A. Linear Regression Analysis

Widely applied in urban transport planning (Golob 1989; Said 1990), regression models quantify the statistical relationship between trip numbers and explanatory variables.

Advantages:

- Simple and interpretable
- Easily calibrated using survey data

- Provides direct coefficients for planners

B. Cross-Classification (Category Analysis)

This method categorizes households based on discrete characteristics (Stopher & McDonald, 1983). Advantages:

- Suitable when variables are categorical
- Easy to apply in large-scale planning

While both methods are valid, regression analysis offers **better numerical precision** and is widely recommended by U.S. BPR and FHWA guidelines (1975; 1967).

12.1.3_Effects of Socio-Economic Variables

The literature consistently highlights the following variables as significant:

- **Household size:** Larger families tend to generate more trips (Downes et al., 1978).
- **Income:** Positively associated with trip rates due to greater mobility resources (Deaton, 1985).
- **Licensed drivers:** Strong predictor of car-based travel (Giuliano & Dargay, 2006).
- **Workers in household:** Directly related to work trips.
- **Educational level:** Often influences school and social trips.

These findings strongly align with the models produced in this study.

12.1.4_International Case Studies

Studies across the U.S., UK, Canada, Australia, and Southeast Asia demonstrate variability in trip generation coefficients, driven by cultural and economic differences.
For example:

- UK's TRICS database (Hunt & Broadstock, 2010) highlights suburban trip rates dominated by car use.
- Research in Metro Manila (Pettersson & Schmocker, 2010) shows that age distribution significantly shapes trip patterns.
- Studies from Gaza City (Mousa, 2013) show strong similarities to Libyan urban conditions.

12.1.5_Gap in Libyan Trip Generation Literature

Despite abundant international research, **Libya lacks locally calibrated trip generation models**. Previous planning practices relied on imported parameters, resulting in inaccurate forecasts. This study directly addresses this gap by building regression-based models using **real household survey data** from **South Tripoli**.

13. 1_General Methodology Steps

The research primarily relies on the following methodology:

1. **Books and Online Research:** This step involves reviewing relevant content, including publications on trip generation analysis using various methods, including linear regression.

2. **Selection of Study Area:** This step includes defining the boundaries of the study area and dividing the city into traffic zones according to a set of criteria, utilizing maps provided by the municipality.
3. **Sample Size Selection and Questionnaire Design for Residential Units:** This step involves determining the necessary information and designing a questionnaire to collect data related to socio-economic variables and trip data.
4. **Data Collection:** This involves gathering field data from a sample of residential units across different traffic zones. The required data includes the total number of trips made by household members, the number of trips per category based on trip purpose or time, collected through household interviews.
5. **Data Analysis:** This is performed using relevant computer software.
6. **Model Building:** This involves estimating potential models for the total number of trips generated by households and for each trip category (by purpose or time) using linear regression.
7. **Model Selection:** Appropriate models are selected using available statistical and logical methods to predict the total number of trips generated by households and for each trip category.
8. **Validation of Results:** This is done by comparing model outputs with actual data and calibrating the variables used in the model construction.

14.1_ Survey Methods

Once the questionnaire is ready, the next step is conducting the actual survey. There are different types of survey methods, each with its own advantages and disadvantages. Before selecting a method, factors such as respondent characteristics, sample size, cost, expected response rate, and study area size must be considered.

- **Face-to-Face Interviews:** Also known as personal interviews, the researcher visits the respondent's home and completes the questionnaire. This method is the most common and effective for collecting detailed and accurate information. There are two types:
  - **Incidental Method:** Short interviews conducted in public places such as shopping centers and tourist sites.
  - **Door-to-Door Method:** Direct interviews at the respondent's home, either immediately or at a scheduled time.

    Advantages: High response rate, more accurate data, better observation of respondents' behavior.

    Disadvantages: More expensive and time-consuming.

- **Telephone Surveys:** Offer ease of access, speed, and lower cost. However, collecting qualitative data can be challenging due to lower willingness to participate and difficulty observing non-verbal behavior.
- **Email Surveys:** Questionnaires are sent via email for participants to complete. **Advantages:** Low cost and fast. **Disadvantages:** Low response rate and less accurate data.
- **Online Surveys:** The internet is used to collect data quickly and efficiently, with automated data entry and higher response flexibility. **Disadvantages:** Difficulty reaching some target groups and potential survey fraud.

14.1.1_ Data Collection Method Used

The survey method used in this study is **door-to-door face-to-face interviews**, as it provides the highest response rate and data accuracy. Additionally, the study area is small, and participants include a diverse population.

15.1_ Sample Size Calculation Methods

There is no single objective answer for determining sample size. Determining the sample size involves balancing:

1. **Too Large a Sample:** Requires significant resources for data collection and analysis, making it very costly.
2. **Too Small a Sample:** May result in highly unreliable results, reducing the overall value of the study.

Therefore, the optimal sample size lies between these extremes, balancing efficiency with study objectives and cost. There are two main methods commonly used to calculate sample size.

15.1.1_ Statistical Formulas for Sample Size

For an infinite population, the sample size can be calculated using:

$n = (Z^2 \times P \times (1 - P)) / C^2$

Where:

- n = required sample size
- Z = standard normal statistic corresponding to the confidence level
- P = proportion of the population with the characteristic of interest (as a decimal)
- C = allowable margin of error (as a decimal)

For a finite population, the sample size is adjusted using:

$n_{adj} = n / (1 + ((n - 1) / N))$

Where:

- n_{adj} = adjusted sample size
- N = total population size

16.1- Linear Regression Method Overview

Several methods are used to analyze trips and their determinants, including regression and classification techniques. Linear regression assumes that the dependent variable (Y) (number of trips) can be predicted based on explanatory variables (X). The regression equation takes the form:

$Y = \beta0 + \beta1X1 + \beta2X2 + ... + \beta nXn + \varepsilon$

Where:

- Y = dependent variable (number of trips)
- X1, X2, ... Xn = independent/explanatory variables
- $\beta0$ = intercept
- $\beta1, \beta2, ... \beta n$ = regression coefficients
- ε = error term

The best-fitting regression line is determined by evaluating the multiple correlation coefficient (R^2), t-tests for coefficients, and the F-test for the model. These calculations can be performed using software such as Excel, SPSS, or XLSTAT.

16.1.1_ Linear Regression Analysis Procedure

The regression model development follows these steps (Hutchinson, 1974):

1. Examine the relationship between the dependent variable and each independent variable to detect nonlinearity. Apply transformations if necessary.
2. Develop a correlation matrix for all independent variables.
3. Analyze the simple correlation matrix to detect potential multicollinearity.
4. Remove one variable from any highly correlated pair to avoid multicollinearity.
5. Propose multiple regression equations using the selected independent variables.
6. Evaluate each model using statistical tests (R^2, t-tests, F-tests) and logical reasoning to ensure validity.
7. Summarize the results and select the best-fitting model.

16.1.2_ Regression Model Building Methods

The most commonly used methods for selecting explanatory variables are forward selection and backward elimination:

- Forward Selection: Starts with a model containing only the intercept. Variables that significantly improve model fit are added iteratively.
- Backward Elimination: Starts with a model including all variables. Variables contributing least to the model (lowest t-test value) are removed iteratively.

This study used backward elimination to develop trip generation models, as it considers all explanatory variables initially and produces robust regression results.

17.1_ Data Analysis Software

Several statistical software packages can be used for data analysis. The **Statistical Package for the Social Sciences (SPSS)** is one of the most widely used programs. SPSS provides a wide range of statistical procedures and tests. Additionally, it offers descriptive statistics such as frequencies, means, and relationships, as well as graphical outputs.

In this study, **SPSS** will be used to estimate trip generation models using the **linear regression analysis method**.

18.1_ Model Specifications

Multiple linear regression analysis is one of the common forms of model structure and can be applied to trip generation models. Accordingly, **multiple regression equations** will be used to develop the trip generation models for this study.

The most common form of trip generation models assumes a **linear relationship**:

$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \ldots + \beta nXn + \varepsilon$

Where:

- $\beta 0$ = constant term (intercept)
- X1, X2, ... Xn = explanatory variables
- $\beta 1, \beta 2, \ldots \beta n$ = partial regression coefficients
- ε = error term, assumed to be a random variable

Regression coefficients are obtained by performing a regression analysis using statistical software. The above equation is referred to as the **multiple linear regression equation**.

19.1_ Model Estimation

After reviewing relevant theoretical content, models will be estimated using **multiple linear regression** by regressing the dependent variable on all explanatory variables.

In this study, trip generation models are divided into three categories:

1. **General Trip Generation Model**
2. **Trip Generation Models by Trip Purpose**
3. **Trip Generation Models by Trip Time**

19.1.1_ General Trip Generation Model

The general trip generation model is calculated according to the multiple linear regression equation described above.

19.1.2_ Trip Generation Models by Trip Purpose

Trip purposes are classified into five categories:

- Work trips
- Educational trips
- Shopping trips
- Social trips
- Recreational trips

Each of these will be estimated according to the general linear regression equation:

$Yi = \beta 0 + \beta 1X1 + \beta 2X2 + \ldots + \beta nXn + \varepsilon$, for i = 1 to 5

Where i represents the five trip purposes.

19.1.2_ Trip Generation Models by Trip Time

Five time-based trip generation models will be estimated:

1. Trips before 8:00 AM
2. Trips between 8:00–9:00 AM

3. Trips between 9:00 AM–12:00 PM
4. Trips between 12:00–4:00 PM
5. Trips after 4:00 PM

These models will be estimated according to trip timing using the regression equation:

$Y_k = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \varepsilon$, for k = 6 to 10

Where k represents the five time periods considered.

20.1_ Statistical Tests

The most commonly used statistical tests for model selection are discussed below.

20.1.1_ Correlation Matrix and Variance Inflation Factor (VIF): Multiple Regression Test

Multicollinearity occurs when two or more explanatory variables are linearly related in a regression model.

- **Perfect Multicollinearity:** Occurs when two or more independent variables are exactly linearly related, resulting in no unique solution for regression coefficients.
- **Imperfect Multicollinearity:** Occurs when independent variables are highly correlated, but the regression equations can still provide unique estimates.

Even with multicollinearity:

1. Regression coefficients remain **Best Linear Unbiased Estimators (BLUE)**.
2. It becomes more difficult to determine the individual effect of correlated variables.
3. Standard errors increase, potentially making t-statistics insignificant.

The **Variance Inflation Factor (VIF)** is used to detect multicollinearity. A VIF > 10 indicates high multicollinearity for that explanatory variable.

20.1.2_ R-Squared: Goodness of Fit

R-squared (R^2), also known as the **coefficient of determination**, measures how well the regression model fits the data. It represents the proportion of total variance in the dependent variable explained by the explanatory variables in the model.

- R^2 ranges from 0 to 1.
- Values closer to 1 indicate a good fit; values closer to 0 indicate a poor fit.

R^2 can be calculated as:

$R^2 = SSR / SST$

Where:

- SSR = Sum of Squares due to Regression
- SST = Total Sum of Squares

ANOVA results are used to show the total variance analysis in the dependent variable, divided into **variance due to regression** and **variance due to errors**.

20.1.3_ F-Test: Overall Model Significance

The **F-statistic** is used to test whether the regression coefficients as a group are equal to zero.

- **Null Hypothesis (H0):** All regression coefficients are zero.

- **Alternative Hypothesis (H1):** At least one coefficient is not zero.

A 95% significance level is generally accepted for the F-test. ANOVA tables are used to present the results of the F-test and overall model significance.

20.1.4_ T-Test: Individual Coefficient Significance

The t-test is used to assess the statistical significance of individual regression coefficients. Generally, if the absolute value of the computed t-statistic exceeds 2, the coefficient is considered significantly different from zero at the 95% confidence level.

21.1_ Logical Criteria for Model Selection

Key logical considerations for selecting the best regression model include:

- Regression coefficients should have the correct sign and reasonable magnitude. For example, an explanatory variable expected to have a positive effect on the dependent variable should not appear negative.
- The intercept (constant term) should be reasonable in value and sign.

22.1_ Study Area Definition

Urban transport planning requires defining a study area that reflects both existing urban zones and potential future development. The study area for this research is **South Tripoli**, delineated using a hypothetical external cordon line. Key criteria for defining this boundary include (Arasan, 2012):

- The cordon line should encompass built-up areas and zones likely to be developed during the planning period.
- It must include all areas relevant to residents' daily activities and travel patterns, particularly those influencing commuting to the city center.
- The line should be continuous, intersecting traffic routes at safe and convenient points for survey purposes.
- The boundary should align with previous or planned studies, including census or demographic surveys

23.1_Study Population and Sampling

23.1.1_Population Enumeration

Due to the lack of accurate official data, an estimated population of the study area in **South Tripoli** was calculated. The average household size was determined from a random sample of 34 households, resulting in an average of **5.12 persons per household** (Table 4-1).

Table (1) Average Household Size in South Tripoli

No.	Number of Households	Number of Individuals	Individuals per Household
1	34	174	5.12

Households were counted across 10 geographic sub-areas, including special accommodations for teachers and displaced persons, totaling **4,429 housing units** (Table).

Table: (2)Housing Units in South Tripoli

No.	Area	Number of Buildings	Number of Housing Units
1	Project 1	120	300
2	Project 2	170	425
3	Project 3	150	375
4	Project 4	180	450
5	Salah al-Din neighborhood	90	630
6	Zohour Neighborhood Buildings	102	714
7	Al Intisar neighborhood	134	670
8	Green Plateau	123	615
9	Gargoor area	80	160
10	Displaced	90	90
	Total		4,429

Table: (3)Estimated Population in South Tripoli

No.	Area	Housing Units	Avg. Individuals per Household	Estimated Population
1	Project 1	300	5.12	1,536
2	Project 2	425	5.12	2,176
3	Project 3	375	5.12	1,920
4	Project 4	450	5.12	2,304
5	Salah al-Din neighborhood	630	5.12	3,226
6	Zohour Neighborhood Buildings	714	5.12	3,656
7	Al Intisar neighborhood	670	5.12	3,430
8	Green Plateau	615	5.12	3,149
9	Gargoor area	160	5.12	819
10	Displaced	90	5.12	461
	Total	4,429		22,677

Sample Size

Using U.S. BPR Guidelines

Following **BPR (1967)** guidelines, the minimum sample size is 10% of housing units for populations under 50,000. Therefore, **443 households** were sampled across 10 sub-areas.

Statistical Formula

Sample size for trip purposes was calculated using probabilities (P) from a preliminary survey of households

Table: (4)Sample Size Calculation by Trip Purpose

Trip Purpose	P	1-P	α	Z	C	Ss	Adjusted Ss
Work	0.22	0.78	0.05	1.96	0.04	412	407
Education	0.29	0.71	0.05	1.96	0.04	494	488
Social	0.17	0.83	0.05	1.96	0.04	339	336
Shopping	0.24	0.76	0.05	1.96	0.04	438	433
Recreation	0.08	0.92	0.05	1.96	0.04	197	196
Total	1.00					1,880	1,860

The statistical sample size was **367 households**, but the BPR-based sample of **443 households** was used for higher accuracy

- Sampling Method

A **stratified random sample** of 443 households was selected from the 10 sub-areas

Table: (5)Sample Distribution by Sub-Area

Area Code	Area Name	Housing Units	% of Total Units	Sampled Units
1	Project 1	300	7%	30
2	Project 2	425	10%	43
3	Project 3	375	8%	38
4	Project 4	450	10%	45
5	Salah al-Din neighborhood	630	14%	63
6	Zohour Neighborhood Buildings	714	16%	71
7	Al Intisar neighborhood	670	15%	67
8	Green Plateau	615	14%	62
9	Gargoor area	160	4%	16
10	Displaced	90	2%	9
Total		4,429	100%	443

23.1.2- Questionnaire Design

The survey instrument was designed to minimize respondent resistance and included:

1. Simple and direct questions.
2. Minimal open-ended questions with coding for responses.
3. Sensitive questions (income, vehicles) placed at the end.
4. Travel information, including trip purpose.

23.1.3_ Required Information

1. **Household Characteristics:** Gender, age, relation to head of household, education, profession, income, vehicles, and driving license.
2. **Trip Data:** All trips made by household members on the previous working day, including trip purpose and time.

Table: (6)Independent Variables

No.	Variable	Description
X1	Household size	Number of individuals in household
X2	Males	Number of male individuals
X3	Females	Number of female individuals
X4	Employees	Number of employed individuals
X5	Graduates	Number of educated individuals
X6	Age <16	Individuals under 16 years
X7	Age 16–30	Individuals 16–30 years
X8	Age 31–50	Individuals 31–50 years
X9	Age 51–64	Individuals 51–64 years
X10	Age >65	Individuals over 65 years
X11	Driving license	Number of individuals with license
X12	Monthly income	Household monthly income
X13	Vehicle ownership	Number of vehicles owned

Table: (7)Dependent Variables

No.	Variable	Description
Y	Total trips	Total trips generated by household
Y1	Work trips	Trips for work
Y2	Education trips	Trips for education
Y3	Shopping trips	Trips for shopping
Y4	Social trips	Trips for social purposes
Y5	Recreational trips	Trips for recreation

No.	Variable	Description
Y6	Pre-8 AM trips	Trips before 8 AM
Y7	8–9 AM trips	Trips 8–9 AM
Y8	9–12 trips	Trips 9 AM–12 PM
Y9	12–4 PM trips	Trips 12–4 PM
Y10	Post-4 PM trips	Trips after 4 PM

23.1.4_ Field Survey Procedure

1. Two trained enumerators were recruited.
2. Random addresses were assigned to each enumerator.
3. Sampled households were numbered on maps and questionnaires.
4. Surveys were conducted at different times of the day, focusing on the previous working day (Sunday–Thursday).
5. Respondents provided travel details; trips by children under 5 were excluded.

24.1_Analysis and Discussion of Results

24.1.1- Description of the Data

This chapter presents and discusses the descriptive and quantitative analyses of the dependent variable (Y) and the explanatory independent variables (X). It further provides an overview of the distribution of household trips according to purpose and time, followed by an examination of the relationships between daily trip generation and each independent variable using graphical and statistical methods.

24.1.2- Descriptive Analysis of the Dependent Variable (Y)

Table: (8)Descriptive Statistics of Total Daily Household Trips

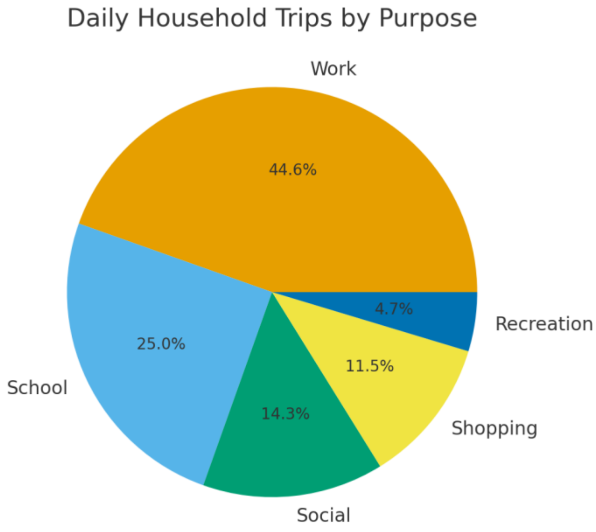
Total Trips	Average Trips/Day	Households	Mean	Std. Deviation	Max	Min	Range
21,188	1,413	443	3.2	23.62	141	8	133

The results indicate that households complete an average of **3 trips per day**, with a minimum of **8** and a maximum of **141** daily trips across the sample.

24.1.3- Trip Generation by Purpose

Table: (9)Daily Household Trips by Purpose

Trip Purpose	Count	Mean	Percentage	Std. Dev	Max	Min	Range
Work Trips	9,443	21.32	45%	14.29	105	0	105
School Trips	5,294	11.95	25%	9.52	45	0	45
Social Trips	3,027	6.83	14%	4.93	30	0	30
Shopping Trips	2,436	5.50	11%	3.48	15	2	13
Recreational Trips	988	2.23	5%	2.93	15	0	15



Work and school trips represent the majority of household travel (70%), highlighting strong links between employment/school enrollment and mobility demand.

Trip Distribution by Time of Day

Table: (10)Trips by Departure Time

Time Period	Count	Mean	Std. Dev	Max	Min	Range
Before 8:00 AM	5,377	12.14	8.95	35	0	35
8:00–9:00 AM	7,251	16.37	12.7	75	0	75
9:00 AM–12:00 PM	2,716	6.13	7.19	45	0	45
12:00–4:00 PM	3,274	7.39	5.76	30	0	30
After 4:00 PM	2,570	5.8	6.06	30	0	30

Morning travel (before 9 AM) accounts for nearly **60%** of total trips, reflecting work and school commuting patterns.

25.1_ Descriptive Analysis of Independent Variables (X)

Below is a selection of the variables rewritten in academic English.

(All values preserved exactly)

Table: (11)Household Size (X1)

Variable	Count	Mean	Std. Dev	Max	Min	Range
Household Size	2,420	5.46	1.77	12	2	10

The average household size is approximately **6 persons**, indicating large family structures typical of the study area.

-2. Descriptive Analysis of Independent Variable: Number of Males (X2)

Table (5-5) presents the descriptive statistics for the variable **number of males**. The average number of males in the study sample is approximately 3.

Table: (12)Descriptive Statistics of Number of Males (X2)

Independent Variable (X2)	N	Mean	Std. Dev	Max	Min	Range
Number of Males	1320	2.99	1.42	7	1	6

25.1.1 Descriptive Analysis of Independent Variable: Number of Females (X3)

Table (5-6) shows that the average number of females in the study sample is approximately 3.

Table: (13)Descriptive Statistics of Number of Females (X3)

Independent Variable (X3)	N	Mean	Std. Dev	Max	Min	Range
Number of Females	1100	2.74	1.36	8	1	7

25.1.2_ Descriptive Analysis of Independent Variable: Number of Employees (X4)

Table (5-7) indicates that the average number of employees in the sample is approximately 2.

Table: (14)Descriptive Statistics of Number of Employees (X4)

Independent Variable (X4)	N	Mean	Std. Dev	Max	Min	Range
Number of Employees	884	1.99	0.94	6	1	5

.25.13 Descriptive Analysis of Independent Variable: Number of Qualified Individuals (X5)

Table (5-8) shows an average of approximately 2 qualified individuals per sample.

Table: (15)Descriptive Statistics of Number of Qualified Individuals (X5)

Independent Variable (X5)	N	Mean	Std. Dev	Max	Min	Range
Number of Qualified	947	2.10	1.34	8	0	8

25.1.3 Descriptive Analysis of Independent Variable: Age Group

Table (5-9) presents the descriptive statistics for age groups, showing an average of around 5 persons per household across different age ranges.

Table: (16)Descriptive Statistics of Age Groups

Age Group	N	Mean	Std. Dev	Max	Min	Range
≤16 years	937	2.11	1.64	9	0	9
17–30 years	525	1.19	1.16	4	0	4
31–50 years	679	1.53	0.79	4	0	4
51–64 years	208	0.50	0.67	2	2	2
≥65 years	67	0.15	0.35	1	0	1

Table: (17)Trip Distribution by Age Group

Age Group	N	Percentage
≤16 years	937	39%
17–30 years	525	22%
31–50 years	679	28%

Age Group	N	Percentage
51–64 years	208	9%
≥65 years	67	3%
Total	2416	100%

25.1.3-Descriptive Analysis of Independent Variable: Driving License (X11)

Table shows the average number of individuals with a driving license is approximately 2.

Table: (18)Descriptive Statistics of Driving License Holders (X11)

Independent Variable (X11)	N	Mean	Std. Dev	Max	Min	Range
Driving License Holders	443	1.79	1.13	6	0	6

25.1.4 Descriptive Analysis of Independent Variable: Monthly Income (X12)

Table shows that the average monthly income is approximately 2110 LYD.

Table: (19)Descriptive Statistics of Monthly Income (X12)

Independent Variable (X12)	N	Mean	Std. Dev	Max	Min	Range
Monthly Income (LYD)	443	2110	1.13	5000	800	4200

Descriptive Analysis of Independent Variable: Number of Cars (X13)

Table indicates that the average number of cars is approximately 2.

Table: (20)Descriptive Statistics of Number of Cars (X13)

Independent Variable (X13)	N	Mean	Std. Dev	Max	Min	Range
Number of Cars	443	1.9	1.02	5	0	5

Quantitative Analysis of Independent Variables and Their Relationship with the Dependent Variable Using Simple Regression

To determine the relationship between the daily number of trips generated per household (dependent variable) and each independent variable, simple linear regression

Quantitative Analysis of Independent Variable: Household Size (X1) and Its Relationship with the Dependent Variable

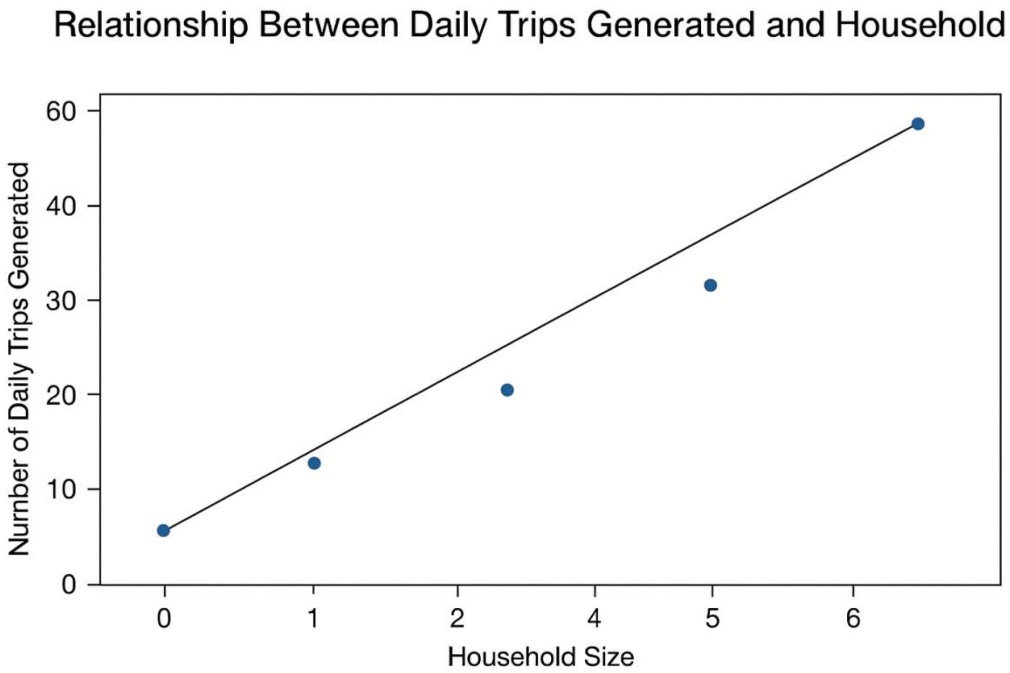
To examine the relationship between daily trips generated per household (dependent variable) and household size (independent variable), simple regression was applied. Tables present the results.

Table: (21)ANOVA Results for Simple Regression to Test the Effect of Household Size on Daily Trips Generated

Source	Sum of Squares	df	Mean Square	F-value	Sig.	R	R^2
Regression	45931	1	45931	100.942	0.000	0.432	0.19
Error	200667	441	455				
Total	246598	442					

Table: (22)Simple Regression Results for the Effect of Household Size on Daily Trips Generated

Variable	Regression Coefficient (B)	t-value	Sig.
Constant β0	16.383	4.980	0.000
Household Size β1	5.756	10.047	0.000



2 Quantitative Analysis of the Independent Variable (Number of Males, X2) and Its Relationship with the Dependent Variable

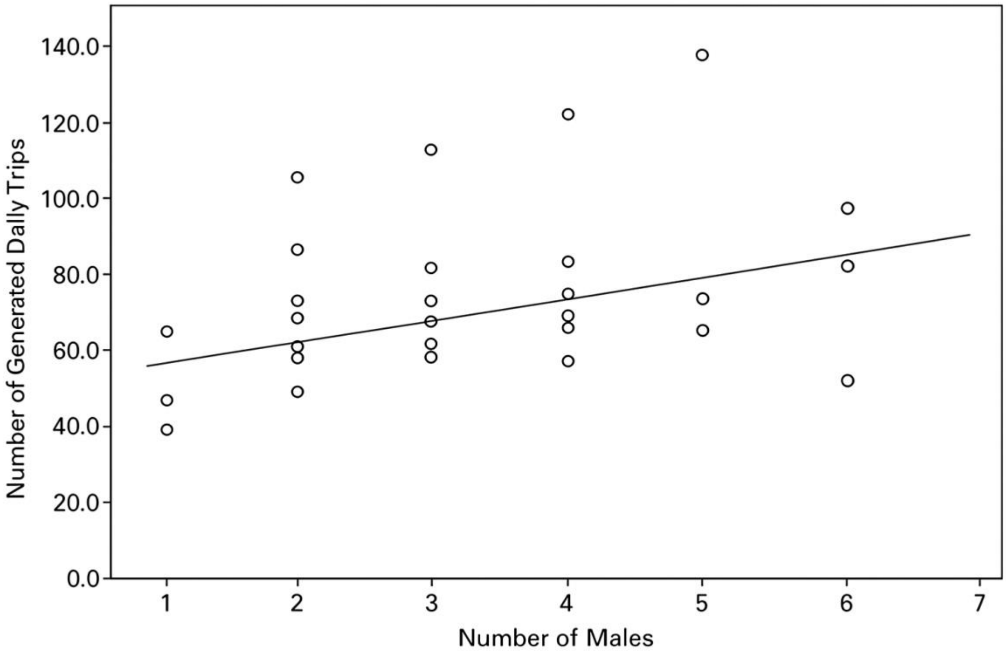
Table: (23)ANOVA Results for Simple Regression to Verify the Validity of the Model for Testing the Effect of the Number of Males on the Number of Generated Daily Trips

Source	Sum of Squares	df	Mean Square	Calculated F-value	Calculated Sig. Level	Correlation Coefficient R	Coefficient of Determination R^2
Regression	58,101	1	58,101	194.24	0.000	0.553	0.306
Error	188,497	441	427				
Total	246,598	442					

Table: (24)Simple Regression Analysis Results to Test the Effect of the Number of Males on the Number of Generated Trips

Variable	Regression Coefficient (B)	Calculated t-value	Calculated Sig. Level
Constant (β0)	20.302	9.289	0.000
Number of Males (β1)	9.210	13.937	

Figure (2) Relationship between the Number of Generated Daily Trips and the Number of Males



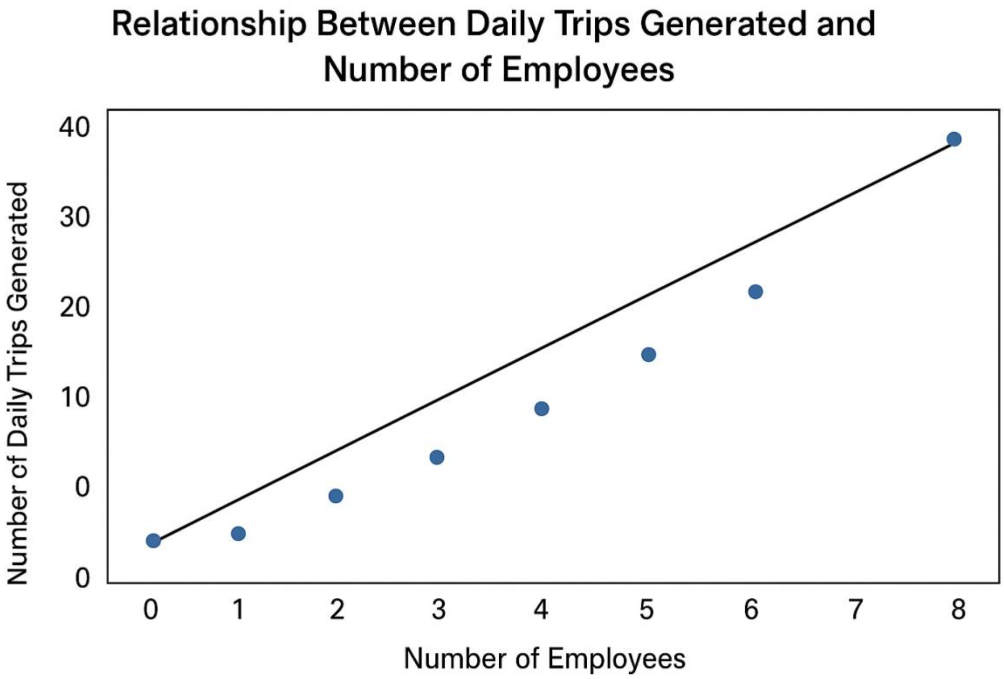
26.1 Quantitative Analysis of the Independent Variable: Number of Employees (X4) and Its Relationship with the Dependent Variable

Table: (25)ANOVA Results for the Simple Regression Analysis to Verify the Validity of the Model for Testing the Effect of the Number of Employees on the Number of Daily Trips Generated

Source	Sum of Squares	df	Mean Square	Calculated F Value	Calculated Sig. Level	Correlation Coefficient R	Coefficient of Determination R^2
Regression	46,170.4	1	46,170	147.656	0.000	0.501	0.251
Error	200,428	441	454				
Total	246,598	442					

Table: (26)Simple Regression Results for Testing the Effect of the Number of Employees on the Number of Generated Trips

Variable	Regression Coefficient B	Calculated t Value	Calculated Sig. Level
Constant β_0	22.951	10.126	0.000
Number of Employees β_1	12.467	12.151	0.00



Quantitative Analysis of the Independent Variables Combined and Their Relationship with the Dependent Variables (Y and Yn) Using Multiple Regression Models

First: Dependent Variables

- **Y**: The dependent variable representing the total number of generated trips.
- **Y1**: The dependent variable representing the number of generated work trips.
- **Y2**: The dependent variable representing the number of generated school (education) trips.
- **Y3**: The dependent variable representing the number of generated social-visit trips.
- **Y4**: The dependent variable representing the number of generated shopping trips.
- **Y5**: The dependent variable representing the number of generated recreation trips.
- **Y6**: The dependent variable representing the number of trips generated before 8:00 AM.
- **Y7**: The dependent variable representing the number of trips generated between 8:00 and 9:00 AM.
- **Y8**: The dependent variable representing the number of trips generated from 9:00 AM to 12:00 PM.
- **Y9**: The dependent variable representing the number of trips generated from 12:00 PM to 4:00 PM.
- **Y10**: The dependent variable representing the number of trips generated after 4:00 PM.

Second: Independent Variables

- **X1**: Independent variable representing household size.
- **X2**: Independent variable representing the number of males.
- **X3**: Independent variable representing the number of females.

- **X4**: Independent variable representing the number of employees.
- **X5**: Independent variable representing the number of educated individuals.
- **X6**: Independent variable representing the number of individuals under 16 years old.
- **X7**: Independent variable representing the number of individuals aged 17 to 30 years.
- **X8**: Independent variable representing the number of individuals aged 31 to 50 years.
- **X9**: Independent variable representing the number of individuals aged 51 to 64 years.
- **X10**: Independent variable representing the number of individuals aged 65 years and above.
- **X11**: Independent variable representing the number of individuals holding a driving license.
- **X12**: Independent variable representing the average monthly income.
- **X13**: Independent variable representing the number of cars.

Third: Regression Model Coefficients for Each Variable

- β_0: Model constant (intercept).
- β_1: Regression coefficient for household size.
- β_2: Regression coefficient for the number of males.
- β_3: Regression coefficient for the number of females.
- β_4: Regression coefficient for the number of employees.
- β_5: Regression coefficient for the number of educated individuals.
- β_6: Regression coefficient for individuals under 16 years old.
- β_7: Regression coefficient for individuals aged 17 to 30 years.
- β_8: Regression coefficient for individuals aged 31 to 50 years.
- β_9: Regression coefficient for individuals aged 51 to 64 years.
- β_{10}: Regression coefficient for individuals aged 65 years and above.
- β_{11}: Regression coefficient for individuals holding a driving license.
- β_{12}: Regression coefficient for the average monthly income.
- β_{13}: Regression coefficient for the number of cars.
- ε: Error term (residual).

Table: (27)To study the combined effect of the independent variables on the total trip generation rate (Y)

Variable	Description of Independent Variable	Regression Coefficient	Coefficient Value	t-test Value	t Significance
Constant	β0	12.561	3.787	.000	
X1	Family Size	β1	45.692	2.505	.013
X2	Males	β2	-32.110	-1.994	.047
X3	Females	β3	-35.071	-2.180	.030
X4	Number of Employees	β4	3.916	3.123	.002
X5	Number of Graduates	β5	2.843	3.898	.000
X6	Age 16 or below	β6	-9.757	-1.181	.238
X7	Age 17 to 30	β7	-14.759	-1.743	.082
X8	Age 31 to 50	β8	-9.348	-1.115	.266
X9	Age 51 to 64	β9	-10.528	-1.269	.205
X10	Age 65 or above	β10	-22.776	-2.644	.008
X11	Driving License	β11	12.928	9.094	.000
X12	Monthly Salary	β12	-0.005	-3.546	.000
X13	Number of Cars	β13	1.796	1.344	.180

Correlation Coefficient: 0.492

Coefficient of Determination (R^2): 0.242

F-Value: 10.555

Significance Level for F-Test: 0.00

Table: (28)regression model table based on the data you provided:

Variable	Description of Independent Variable	Regression Coefficient (β)	Coefficient Value	t-test Value	Significance (Sig)
(Constant)	–	β0	17.647	8.610	0.000
X4	Employees	β4	3.493	3.069	0.002
X5	Graduates	β5	2.299	3.147	0.002
X11	Driving License	β11	10.265	10.237	0.000

Model Statistics:

- Correlation Coefficient (r): 0.669
- Coefficient of Determination (R^2): 0.447
- F-Value: 118.488
- Significance Level for F-Test: 0.000

Study of the Effect of Independent Variables on the Trip Generation Rate for Work Trips (Y1)

Table: (29)Results of the Multiple Linear Regression Model for Trip Generation for Work Trips (Y1)

Variable	Description of Independent Variable	Regression Coefficient (β)	Coefficient Value	t-test Value	t Significance (Sig)
Constant	–	β0	-0.618	-0.325	0.745
X1	Household Size	β1	-12.071	-1.154	0.249
X2	Males	β2	15.565	1.686	0.043
X3	Females	β3	15.631	1.694	0.041
X4	Number of Employees	β4	1.460	2.031	0.043
X5	Number of Graduates	β5	1.891	4.520	0.000
X6	Age ≤ 16	β6	-3.133	-0.661	0.509
X7	Age 17–30	β7	-5.845	-1.204	0.229
X8	Age 31–50	β8	-0.659	-0.137	0.891
X9	Age 51–64	β9	0.882	0.185	0.853
X10	Age ≥ 65	β10	-0.966	-0.196	0.845
X11	Driving License	β11	6.185	7.587	0.000
X12	Monthly Salary	β12	0.003	3.291	0.001
X13	Number of Cars	β13	2.610	3.407	0.001

Model Statistics:

- Correlation Coefficient (r): 0.781
- Coefficient of Determination (R^2): 0.610
- F-Value: 51.546
- Significance Level for F-Test: 0.000

Table: (30)Regression Model Table for Independent Variables Affecting the Dependent Variable Y1 in the Revised Form

Variable	Description of Independent Variable	Regression Coefficient (β)	Coefficient Value	t-test Value	t Significance (Sig)
B	Constant	β0	4.241	4.166	0.000
X5	Number of Graduates	β5	1.896	4.465	0.000
X11	Driving License	β11	7.310	14.474	0.000

Model Statistics:

- Correlation Coefficient (r): 0.689

- Coefficient of Determination (R^2): 0.475
- F-Value: 199.223
- Significance Level for F-Test: 0.000

Results and Recommendations

Introduction

The South Tripoli area was selected as the study area to analyze traffic (TAZs). To create representative samples, the study area was divided into 10 points, and samples were randomly selected from each of the 10 points. The sample size was determined to be 443 households.

Household interviews were conducted with the selected samples to obtain the necessary data using a questionnaire. Multiple linear regression, a widely used method for predicting generated trips, was applied in this study.

Three types of trip generation models were developed:

- **Type 1:** The general trip generation model.
- **Type 2:** Trip generation models by trip purpose, specifically: work trip generation model, education trip generation model, shopping trip generation model, social trip generation model, and recreational trip generation model.
- **Type 3:** Five time-based trip generation models were estimated according to time periods: morning peak period (before 8:00 AM), trips generated between 8:00–9:00 AM, trips generated between 9:00 AM–12:00 PM, trips generated between 12:00–4:00 PM, and evening peak period (after 4:00 PM).

Results

The main findings can be summarized as follows:

1. The general trip generation model has a reasonable explanatory power, with **R^2 = 0.45** and a **correlation coefficient = 0.669**, indicating that the explanatory variables included in the model account for 45% of the variance in daily trips per household. The variables that mostly affect the number of daily generated trips are: number of employees, number of graduates in the household, and number of household members holding a driving license. This result does not align with the findings of a previous study conducted in developing and developed areas in South Tripoli, due to differences in the study environment and indicating good explanatory power.
2. As expected, the most important variables affecting the general trip generation model for education trips (school trips) are household size and number of household members aged 65 and above, with **R^2 = 0.203** and **correlation coefficient = 0.541**, indicating acceptable explanatory power.
3. The shopping trip generation model had **R^2 = 0.24** and **correlation coefficient = 0.493**, meaning that the explanatory variables included in the model explain 24% of the variance in shopping trips. Explanatory variables most relevant to this model are: number of graduates in the household and number of household-owned cars.

4. The social trip generation model had **R^2 = 0.182** and **correlation coefficient = 0.427**, explaining 18% of the variance in social trips per household. The most relevant variables are: number of males in the household, number of females in the household, and number of graduates in the household.
5. The main explanatory variables in the recreational trip generation model are driving license and number of household members aged 31–50, with **R^2 = 0.18** and **correlation coefficient = 0.427**, indicating that these two variables explain 18% of the dependent variable. The explanatory power is not strong in this model.
6. The time-based trip generation models for the periods 9:00 AM–12:00 PM and 12:00–4:00 PM have the highest **R^2 values** among all time-based models, **0.33 and 0.21**, with **correlation coefficients = 0.574 and 0.436**, respectively. This is because most trips occur during these peak periods and are well correlated with relevant independent variables.
7. The trip generation model for the peak period 9:00 AM–12:00 PM has **R^2 = 0.33** and **correlation coefficient = 0.574**, meaning explanatory variables account for 33% of the variance in trips during this period. The most relevant variables are: number of graduates in the household, number of household members aged ≤16, number aged 31–50, number aged ≥65, and number of household-owned cars.
8. The trip generation model for the period 12:00–4:00 PM has **R^2 = 0.198** and **correlation coefficient = 0.436**, meaning explanatory variables account for 19.8% of the variance in trips during this period. The most relevant variables are: number of males in the household and number of household members aged ≥65.

Recommendations

1. It is recommended to develop trip generation models using **non-linear regression** as a primary tool for travel demand modeling to achieve better future traffic flow modeling and improve urban transport planning in Libyan cities.
2. Encourage researchers to examine the possibility of transferring the estimated models in this study to other Libyan cities and municipalities.
3. The results of this research should be compared with trip generation models developed in other cities.
4. For planning any Libyan city, it is recommended to follow the procedures described in this study, adopting regression analysis as part of trip generation modeling for urban transport planning.
5. The Libyan General Information and Statistics Authority should conduct **household travel surveys** including detailed trip data, which researchers can use to estimate trip generation models.

6. Collect new data sets and use them to validate the model after a period of time to ensure the models remain accurate.
7. Future data collection should be used in the developed models to ensure their continued validity by comparing estimated trips from the models with observed trips.

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