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HOW DO THE SOCIO-ECONOMIC INDICATORS INFLUENCE THE TRAVEL BEHAVIOUR PATTERN? CASE STUDY AMMAN-JORDAN

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Limited research has been conducted in developing countries on travel behavior and its prediction. This study aimed to investigate if socio-economic conditions affect travel behavior patterns in Amman, Jordan, and propose regression models for trips defining the contributory factors. A total of 681 interviews were conducted with households (210) and workplace employees (335), assessing behavioural travel styles in two neighbourhoods with different characteristics. Compared to residents of high-income areas (HIA), residents of low-income areas (LIAs) travel more by all modes of transportation; in LIA and HIA, the trip rate per person was (2.2) and (2.0), respectively, while in low-income and high-income areas, the number of trips per household was 5.14 (153.6 minutes) and 3.7 (155 minutes). Most household trips in low-income neighbourhoods, mainly for education and work, were made on foot, while private cars were more common in high-income areas. For trips related to the office and shops, the private car was the most common mode of transportation. In low-income neighbourhoods, shared taxis were commonly used for household and shop trips, and buses were often used for commutes. School and university students, as well as household size, provided valid trip predictions. Employees can predict work trips to the office, customer visits, and shop-related trips.

Keywords: travel, behaviour pattern, income level, regression analysis

1 INTRODUCTION

1.1 Urbanization and Mobility

Cities, by definition, are places or areas in which many people live close together performing economic activities over space. The interaction between the space and the people is regulated and organized by the municipalities or local governments. One of cities functions is providing and maintaining utilities and transportation systems. The UN estimates that 55% of the world's population in 2018 lived in urban settlements [1]. Around 32% of the population lives in cities with more than 300,000 people, and the remaining live in Urban settlements with fewer than 300,000 people. The UN projections for 2050 indicate a high level of urbanization in Asian countries, with countries like Jordan, Qatar, Jordan, Oman, Kuwait, and Japan will be the most urbanized population [2]. The urbanization is associated with many challenges, but the mobility is the most predominant one across the globe. Mobility is an essential element of modern life; without any doubt the participation in the economy or in any, social and cultural events and other activities can't be completed without some form of travel.

1.2 State of Art of Travel Behaviour Pattern

A literature review of the more recent publications on travel behaviour modelling (TBM); a taxonomy was developed, classifying the advances in the research work based on the type of algorithms, applications, data sources, technologies, behaviour analysis, and datasets. The work also summarized some characteristics of TBM models by model and data types and the data size to shed light on future work. The review ended with recommendations for optimizing the common existing datasets and some direction for future works defining the challenges and related objectives, including the emerging challenges and rising opportunities like integrating autonomous vehicles and intelligent traveling. A recommendation for advancing the behaviour models includes developing methods for suspicious behaviour prediction and improving the case detection of sudden behavior change that may be elaborated in future work for better travel demand prediction and producing automatic behaviour graph generation [3]. An international literature review of multimodal trip generation associated with land use developments based on 153 publications was conducted.

The review of the modelling studies of the impact of automated vehicles on transport mobility shows a potential increase in vehicle miles travelled and a decrease in the use of PT and slow modes share. On the other hand, shared automated vehicle fleets would reduce vehicles and parking spaces. Further, the automation process would increase the efficiency of the PT system [4]. The review showed that multimodal trip generation studies recently started to receive more attention. The review identified issues related to the estimation and the application of the multimodal trip generation rates, including the lack of sufficient data and higher complexity in data collection, particularly if compared with vehicle trip generation studies. The study concluded by stating the importance of developing an international multimodal trip generation database and sharing the data that would help bridge the knowledge gap, emphasizing the importance of using technology to assist with data collection [5].

A state-of-the-art review of panel data (repeated measures of the same individuals) for understanding travel behaviour dynamics has been conducted, considering seven research papers [6]. The opposite of panel data is the cross-section data, which studies differences between individuals at one point whereas the panel data study changes

'within' individuals over time. A study from Germany showed that gender affects activities and time use. For women, family affects their time use more than men, while labour market event is what influences men's choice [Scheiner, 2016 Cited in 6]. The reviewed papers examine the relationship between car use and travel attitudes toward the built environment, which has proven to be small and significant [Cao et al, 2009 cited in 6]. Another paper looked into how relations inside households affect mode choice, particularly the decision to use the car for home-based trips in the Netherlands by a multilevel binary logit model. The findings showed the interactions between household members, resulting in joint travelling patterns and car use [Olde Kalter and Geurs, 2016 cited in 6]. Data from 230 households in the Puget Sound of the USA were examined to relate four levels of car mobility groups (from low to high) to a wide range of explanatory variables (socio-demographics, attitudes, and land use characteristics) and complex dynamic models [McBride et al., 2016 cited in 6].

1.3 Travel and Contributory Factors

It is traditional for household surveys to determine travel behaviour patterns and demands without taking into account children's travel behaviors. In order to fill the knowledge gap, a large dataset from the Netherlands was descriptively analyzed. It concluded that children's activity-travel behaviour is significantly different from the behaviour of household heads. Children tend to travel less, stay close to their homes when they travel, and appear less dependent on the car. As they grow and become less dependent on their parents, the travel pattern becomes like household heads with different start times of trips, and they travel more for leisure purposes [7].

Data from New Zealand showed that 29% of the kilometre travelled by households are for social and recreational purposes that occur at all times of the day, all days of the week, and with unlimited destinations. The analysis of 18,299 trips over three years indicated that social and recreational trips are not often made by walking, increasing CO2 emissions [8]. Walking distance from home to access PT is investigated in Sydney, Australia, and the distributions of walking distances are different for each mode and its attributes [9].

Three data sets were analysed in the UK describing travel behaviour patterns in Scotland, Manchester, and national levels using univariate and multivariate statistical techniques. The proportion of Manchester's city centre households with no car (48%-55%) is considerably higher than the national averages of Scotland and England. Around 50% and over 60% of the daily journeys in Scotland and Manchester are conducted on foot, respectively. The average number of weekday trips is about 3.3, and the corresponding averages per household were 5.88 and 5.26 for Scotland and Manchester, respectively. The primary purpose of travelling is work, followed by education. Walking is a common mode for commuting, shopping, and leisure. Manchester's data indicates that 42% of the residents' journeys were conducted within the city centre catchment area [10]. Several studies worldwide suggest that residents of high-density and high-land-use mixture neighbourhoods tend to walk more and drive less than the residents of low-density and the low mixture of land-use areas [11].

The travel satisfaction of 1,650 respondents who were relocated to selected neighbourhoods in Ghent (Belgium) and therefore changed their daily travel patterns was analysed based on a two-step approach, factor analysis, followed by cluster analysis. Results indicate that decreased travel distance and duration and increased use of car alternatives are associated with high levels of travel satisfaction for both commute and leisure trips. The study highlighted the need for additional motivation to convince more people to relocate to urban areas increasing the densification and the land use mixing of existing neighbourhoods, improving sustainability and more satisfying travel patterns [12]. In Ghana, a study was conducted to look into the PT mode preferences of international tourists by interviewing 479 tourists upon their departure from the airport. The most frequent transport modes observed to be taxis (31.5%), mini-busses (29.3%), and buses (28.6%), and the least common were motorcycles/bicycles (10.6%). The modal choice factors include affordability, accessibility, availability, safety, and comfort [13].

In Dublin, a pilot postal household survey has been administered to survey the mode choice for non-work trips. The main finding stated that people who drive to work, school, and college also drive non-work activities. For instance, around 45% of the respondents drive to the local convenience shops, while 33% walk. The proportion is even higher when looking into supermarket shop trips, as 62.5% drive their cars compared to 32.5% who walk to the supermarket [14]. Further, there was an association between the land use–transport configuration and mode-share for non-work journey purposes. Socioeconomic characteristics, such as income and car ownership, affect travel behavior pattern, which is in agreement with findings from India, which found socioeconomic factors have the greatest effect on mode choice [15]. The economic capacity of the individual decides the transport mode one can use. In contrast, the socially and physically distressed areas were more inclined to cycle and walk for mobility [16].

Three thousand questionnaires were administered in three Nigerian universities to investigate commuting trips' spatial patterns. Face-to-face interviews were completed with staff and students. The study revealed that the most common transport modes are shuttle buses and private cars. Trip distance is an essential factor in determining travel behaviour patterns. The longer the distance is, the lower the travel by private cars, walking, and bicycle use is. University staff tended to use private cars, while walking was common for private universities, and shuttle buses were common for federal universities [17]. The sociodemographic characteristics of high-density residents in Nigeria were considered to study their travel patterns. Male trip frequency is higher than females, and their income in the study area significantly affects the transport mode choice [18].

1.4 Trip Generation Modelling

Trip generation models for Al-Diwaniyah city of Iraq considered the socioeconomic characteristics and the prevailing land use. A questionnaire was administered to 3400 households, and the turned-in rate was 74.65%. The stepwise regression technique was applied in the analysis, where the dependent variable was the daily household trips. The findings showed that the association between the predictor variables and the dependent variable was statistically significant with family size, gender, the number of workers, and the number of students in the family [19]. The trip generation models for trips made by motorcyclists for non-mandatory activities, excluding trips to other than work or school, were completed using the multiple linear regression analysis to determine the dominant factors that affect these trips. A questionnaire was distributed to 400 families residing in Lhokseumawe City, Indonesia, and home interviews were conducted. The results showed that motorcycle driving license ownership, homemakers, school-age children, middle-income household, and lower education levels influenced non-mandatory motorcycle trips [20]. Trip generation/attraction models have been developed by considering zonal data from Santander metropolitan area (in Spain) and applying the classical regression model, the spatial lag model, and the spatial error models. The spatial lag regression model provided the best fit model relating the trip attracted generated between 7:00 and 9:00 am to the most valid predictors that include residential density, extractive industries occupancy, agricultural cooperatives occupancy, and directors and managers of non-agricultural premises, senior officials in the public administration, autonomous communities, and local authorities [21].

1.5 Mobility and Travel Pattern in Jordan

In 2021, the estimated population of Jordan was 11,254,045, with an expected growth rate of 1.4234%. Around 91% of the country's population lives in urban areas; the proportion of the urban population reaches 97.2% in the capital city [22]. Amman will remain to have the highest urban population in the country until 2044 [23], and it is one of the fastest-growing cities globally. The city grew from 5,000 to more than four million over 100 years, which may be attributed partially to the crises in its neighbouring countries and the continuous pressure of the refugee influx. Amman is 1,048 km² divided into 22 administrative districts inhabited by 42% of Jordan's population. The density varies by district; it is estimated to be in the range of (300 - 8,300 people/km2) for the western districts, while it is between1,500 - 29,000 people/km2 for the eastern districts.

The primary public transport (PT) service in Amman's primary public transport (PT) service Amman is bus-based; other services include shared taxis and taxis. Around 48% of Amman's built area provides access to PT within 300 m, and about 64% is provided within 500m [24]. On average, the single one-way PT trip is 35 minutes with an average cost ranging between 0.30 to 2 JD (0.45 - 1.4 US$). PT is less attractive than private cars as only 13% of all trips are made by PT, according to Amman Transport Mobility Master Plan (TMMP) [25] completed in 2008. Walking trips account for 25% of all travel in the city. The study showed that education followed by work is the primary purpose of travelling in Amman City.

PT in Jordan is described by low fleet capacity, which results in a high level of crowdedness on-board and with no timetables and easy transfer. Safety, as defined by the number of road accidents and their consequences, is a decisive factor when selecting the mode of transport. Buses in Jordan are frequently involved in crashes. Further, the elderly above 60 and children under 15 are the highest risk group. Poor road and street conditions contribute to accidents due to inadequate standards and designs for walking or cycling. Public transportation is linked with walking; the high temperature in Summer and the rugged topography makes people reluctant to use public transit. The first-choice alternative to transport is the personal private car. The total number of vehicles per national statistics in 2021 was 1,794,073, 70.5% of which were private cars. The car ownership level is one car per 8.9 people. It would have been much higher if Jordan had not accommodated these high influxes of refugees in the last decade.

Trip-generated rates for hospitals in Amman were determined based on surveying twenty-one sites on average weekdays. Institute of Transport Engineers (ITE) trip rates were compared with the observed trip rates. ITE trip rate (1.31 vehicle trips/bed) underestimated the observed rate (1.84 vehicle trips/bed). The number of beds and the hospital's gross floor areas was the main factors affecting facility-generated trips [26]. A household survey that includes 2,500 interviews in Irbid, the second-largest city in Jordan, was completed to develop trip generation rates for residential areas. The main findings stated that family size, car ownership, and income level contribute to the generated number of trips. Home-based work trips compose one-third of all home-based trips. Trips on weekends account for one-third of the weekday trips. In contrast to the hospital trip rates, the number of trips generated by residential areas is lower than in developed countries [27].

2 STUDY OBJECTIVES

This literature review has shown little has been done in Jordan to understand travel behaviour patterns. The impact of social and economic factors on travel patterns has not been investigated. This study aims to address this knowledge gap by fulfilling the following objectives: attempt to understand travel behaviour patterns in Amman and analyse if it differs due to the regional socio-economic conditions; develop models to predict the daily generated or attracted trips and examine if the socio-economic influence their magnitudes.

3 METHODOLOGY

The study area was defined as a model for the city's different regions where data should be collected addressing the research objectives. The adopted research methodology is summarized in Fig.1, showing the survey types, related data and analysis methods by mode of transport.

3.1 Study Area

The selected two districts are located in the old part of Amman city, historically reflecting two different living styles: population density, building codes, and other socio-economic indicators. Basman, located in the city's eastern part, is the most populated district. It is one of the seven districts historically made up of the old Amman. Basman comprises six neighbourhoods with an area of 13.44 km^2 and 373,981 (2015 census). It serves residential, commercial, and primary services purposes. The building architecture shows that the district has public folk style, as most housing zones are small houses and apartments. The narrow streets and the numerous intersections are busy with daily traffic. The mean annual household income is 14,100 US$, which is almost the average household income in the city. Zahran is one of the wealthy areas of Amman. It comprises five neighbourhoods with an area of 13.82 km^2 and 107,529 (2015 census). The district witnessed rapid development over time, and its building style in large is modern. It serves residential and commercial land use purposes. The districts' wide streets and, large intersections, grade-separated junctions are often subjected to a high congestion level throughout the day. The mean annual household income is 28,000 US$, one of the city's highest income groups. Table 1 shows that although the area of both districts is almost the same, the population of Basman is nearly four-fold that of Zahran. The road network length in Basman is slightly higher than in Zahran because it was developed earlier and considered older. The income of the households in Zahran is double the one in Basman.

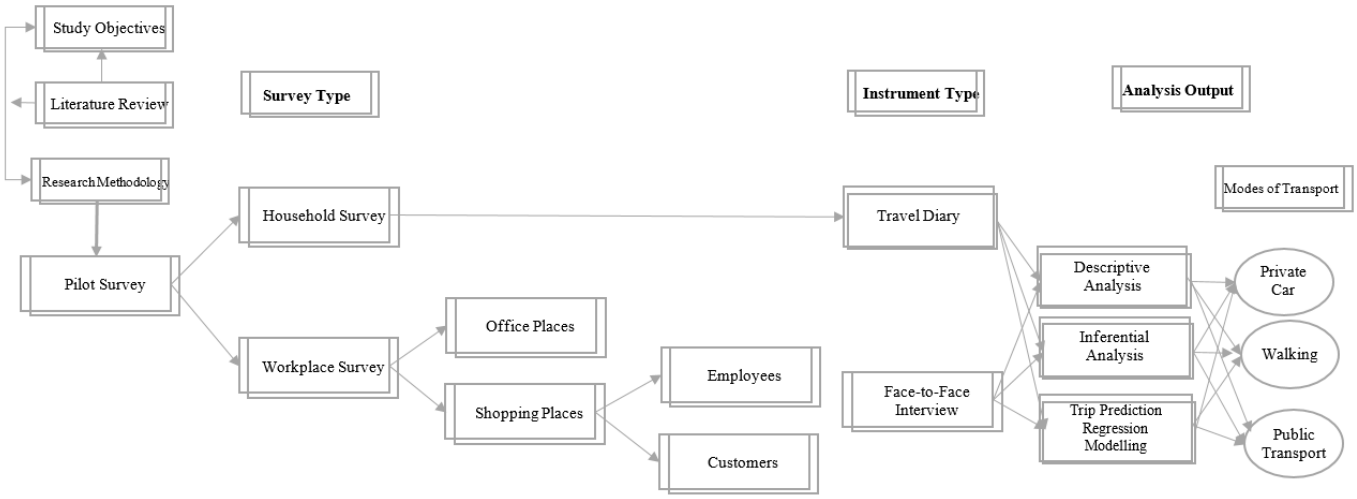
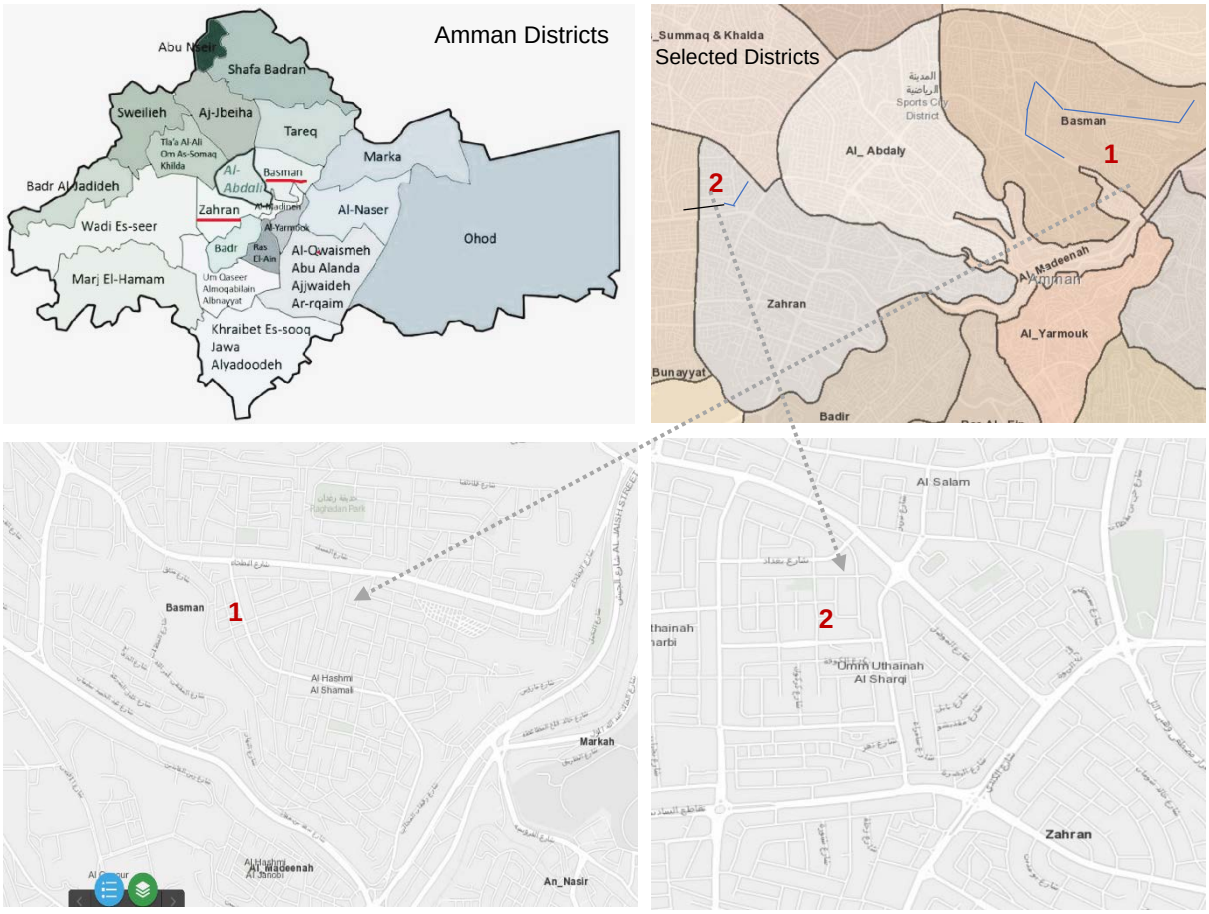


Fig.1: The Study Layout Design

Table 1 Socio-Economic Indicators of the Study Area

District	Population	Area Km^2	Density People/km^2	Network Density km/km^2	Road network length km	Pedestrian Crashes (No)	Average Household monthly Income (US$)
Basman	373,981	13.44	27372.0	1.846716	248.254	5	1,175
Zahran	107,529	13.83	7,774.0	1.5783	218.329	6	2,330

Two neighborhoods were considered models are reflecting different city characteristics for field data collection purposes, one from each district (Al-Hashimi Al-Shamali neighborhood from Basman district and Um-Uthaina neighborhood from Zahran district- Fig.2). Al-Hashimi Al-Shamali, from now on will be referred to as a low-income-area (LIA), is one the largest neighbourhood in the district in terms of population, with 95,000 (2015 census) residing over an area of three kilo-meter square. Commercial activities in the area are limited to small businesses, such as small shops or offices that hire few employees. The 133 streets within the study area are mainly described as narrow streets. They are not well-lit and lack proper signage and marking system. Although some sidewalks are wide, the sidewalks are in poor condition, which also applies to pedestrian crossings. Due to the lack of enough parking stalls, double parking violations are common practices increasing the congestion levels in the area. Different PT modes serve the community, including buses, white taxis, the most common, and the yellow taxi. In 2015, 2,404 crashes were reported on the street network, including 74 pedestrian crashes.



Al Hashmi Al Shamali Neighbourhood UMM Uthainah Neighbourhood

Fig.2 Study Area District and Neighbourhood

Um-Uthaina, from now on, will be referred to as a high-income area (HIA); it is one of the smallest neighbourhoods of Zahran District. It does not have a high population density as its inhabitants do not exceed (21,000) and reside in an area of (1.156) km2. High standards of living in this area can be seen from the architectural style of the buildings. The neighbourhoods host several governmental and commercial buildings—wide-well-lit streets (51) with wide sidewalks and marked pedestrian crossings equipped with speed humps. The roads are furnished with traffic signs but poorly maintained. Available car parking spaces are inadequate, particularly on commercial streets. Intersections witness a safety problem, partially because of the poor geometric design lacking adequate control devices. Due to the poor public transportation system, car dependency is high. In 2015, 2,672 crashes were reported on the street network, including 48 pedestrian crashes.

3.2 Data Collection

To fulfil the objectives of this study, the residents, and visitors of two selected neighbourhoods in Amman were interviewed face-to-face or asked to fill in questionnaires and return them once completed to the survey's administrator. Six different questionnaires were prepared and administered (Fig.1). Each form is designed to explore one or more aspects of travel behaviour patterns within the study area. Different styles of questions were incorporated into the study questionnaires. The responses to some questions have only two categories, while others have four. The first general questionnaire addressed all respondent categories (residents, employees, shop owners, and visitors). The survey is a pilot to help the author develop the appropriate instruments to fulfil the study objectives. Twenty-two questions were drafted, including sub-questions exploring the use of different modes of transport (private car, walking, and PT). Two forms of questionnaires were prepared to address household travel behaviour patterns. A travel diary was handed over to the household head, who was asked to provide data for all household members on one typical weekday. The responses cover the start and end time, the purpose of the trip, and the used mode of transport. The face-to-face household interview covers information about the resident type, household structure, vehicle ownership, and travel behaviour pattern used to cross-check the results of the travel diary survey.

The shop-owner interview provides data on the ownership type, structure, and physical dimensions of the shop and the travel behaviour pattern of the owner and employees. The shop owners were required to assess the attributes of the transport modes and to weigh, from their perspectives, the level of investments and attention the municipality allocated for different modes of transport on a ten-point scale. The same types and levels of data were sought from the manager of the workplaces in the study area. The managers were requested to describe the workplace: available space, working hours, number of employees, and nature of the work. The manager and employees reported on their

travel behaviour patterns. The customers of the workplace and shops were also interviewed to explore their travel behaviour patterns, including trip attributes, vehicle ownership, and their assessment of transport modes' safety.

3.3 Sample Size

The sample size was initially calculated based the following formula that takes into consideration an assumed population proportion, confidence interval and permitted error.

$$n = \frac{z^2 x\, \hat{p}\,(1-\hat{p})}{\epsilon^2} \quad (1)$$

Where,

z is the z score at 95% confidence level
ε is the margin of error (5%)
$\hat{p}$ is the population proportion
n is the sample size

requested $\hat{p}$ of 10% was considered for the household survey, almost achieved for the LIA but not for HIA. Table 2 shows that the requested sample size was 139 interviews. The collected sample size was slightly less by two interviews in the LIA, resulting in a $\hat{p}$ value of 9.85% (137 interviews representing 0.21% of the neighbourhood households), and due to logistics issues, only almost half of the requested interviews were collected in the HIA (73 interviews representing 0.27% of the neighbourhood households) resulting in a $\hat{p}$ value of 5%. The requested $\hat{p}$ of 10% was also considered for the workplaces as shops and 5% for offices because it was anticipated that the office managers and employees would be more reluctant to participate in the survey, which was eventually the case. Almost half of what was requested as a sample size was achieved for the offices' and two-thirds of the shops' surveys.

Table 2 Sample Size Calculations by Survey and Study Area Types

Area	Household Survey			Requested Sample		Collected Sample		Sample Size Proportion	
	Requested sample	collected Sample	Sample Size %	Office	Retail "Shops"	Offices	Shops	Offices	Shops
LIA	139	137	9.85%	73	139	57	95	3.8%	6.6%
HIA	139	73	5%	73	139	34	97	2.25%	6.75%
Total	185	210		146	278	91	192		

The collected sample provides data for different age groups, gender, and place of residence or workplaces (Table 3). The household survey sample constitutes the largest sample size of all sorts of surveys, followed by shops as a workplace, while the customer interview sample is the smallest. The proportion of males in the collected sample is higher than females as 60.1% of all interviewed were males compared to 38.3% of females. The aggregated collected data showed that the sample is equally divided by neighbourhood. Still, some differences exist between the distribution of collected data by the selected neighbourhood for some surveys.

Table 3 Sample Size Distribution by Gender, Age, Area and Survey Types

Survey Type	Sample Size	Gender		Age			Residence/Work Place (Area)	
		Male	Female	<25	25-60	≥60	LIA	HIA
General "Pilot"	136 (20%)	69 (50.7%)	67 (49.3%)	29 (21.3%)	100 (73.5%)	7 (5.1%)	57 (41.9%)	79 (58.1)
Household-Travel Diary	210 (30.8%)	108 (51.4%)	92 (43.8%)	120 (57.1%)	84 (40%)	6 (2.9%)	137 (65.2%)	73 (34.8%)
Workplace: Shop	192 (28.2%)	151 (78.6%)	41 (21.4%)	37 (19.3%)	147 (76.6%)	8 (4.2%)	97 (50.5)	95 (49.5%)
Workplace: Office	91 (13.4%)	62 (68.1%)	29 (31.9%)	20 (22%)	65 (71.4%)	6 (6.6%)	34 (37.4%)	57 (62.6%)
Customers	52 (7.6%)	19 (36.5%)	32 (61.5)	11 (21.2%)	41 (78.8)	-	27 (51.9%)	25 (48.1%)
Total	681 (100%)	409 (60.1%)	261 (38.3%)	217 (31.9%)	437 (64.2%)	27 (4%)	352 (51.7%)	329 (48.3%)

3.4 Analysis Approach

The statistical analysis approach for the collected data is shown in Fig.3. The descriptive analysis includes frequency and measures for central tendency and dispersion (mean and standard deviation). Graphical presentations were included where relevant. The inferential tests include t-test, chi-square, and ANOVA, a significance level of 5% was used in the analysis.

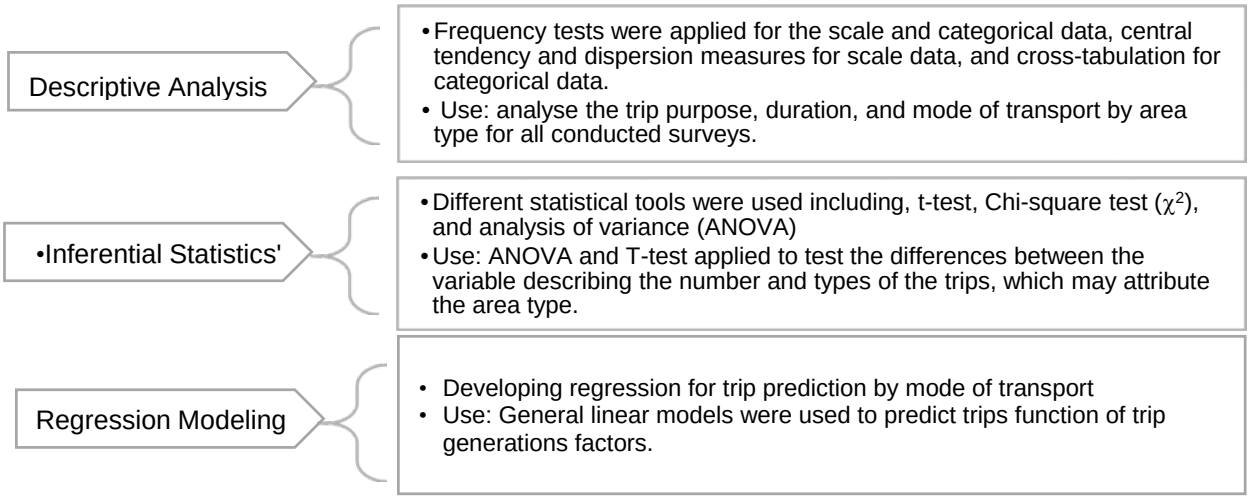


Fig.3 The Study Analysis Approach

General linear modeling (GLM) method was used in developing trip generation models. The three components of the GLM are defined below, namely the random component, define the probability distribution of the response variable (Y or μ), which follows the Normal distribution. The systematic component describes the linear predictors of the model, including the explanatory variables (x_1, x_2, ..., x_i) and their coefficients $\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_i x_i$. The third component is the link function g (μ), linking the random and systematic components, which is assumed to be an identity function in this study.

The dependent variables were selected to predict the number of daily trips produced by households and attracted by workplaces (offices and shops). Each mode of transportation was modeled using a household-based approach. Several variables were assessed for their validity as predictor variables based on the literature review presented in section 1, best practices for estimating trip generation rates, and models such as ITE trips generation manual [28]. These variables differed depending on whether they predicted attracted (workplace) or produced (household) trips. The predictor variables for the produced trips models include the household size, number of schools and university students, and number of employed household members. The workplace-based model predictor variables include the facility area, the number of employees, or divided by gender. In all models, a dummy variable was introduced to describe the geographical location that reflects the socio-economic condition of the neighborhood.

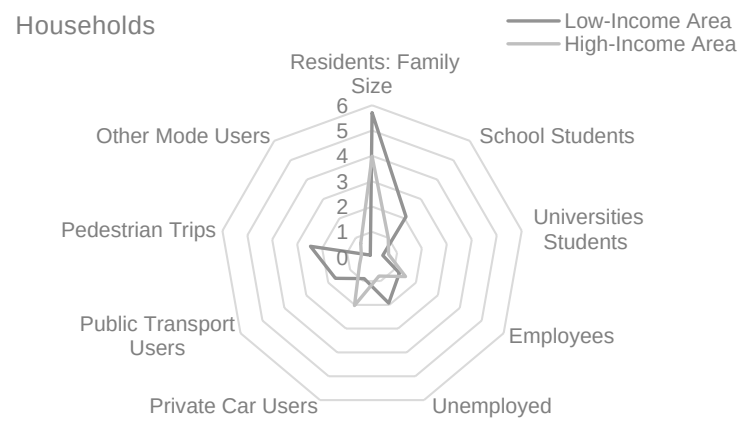
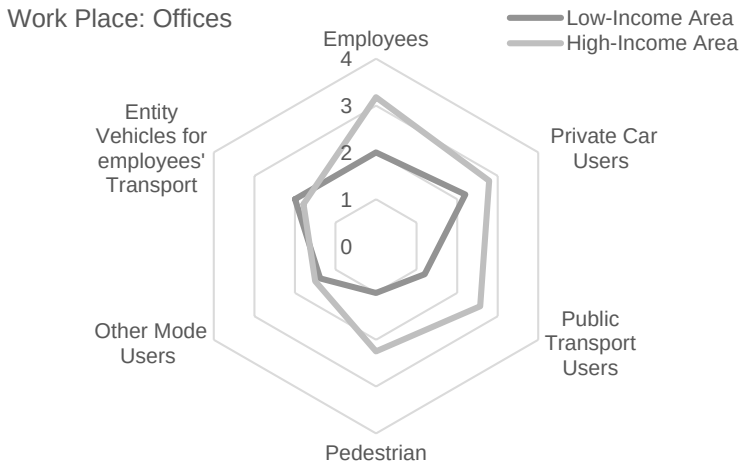
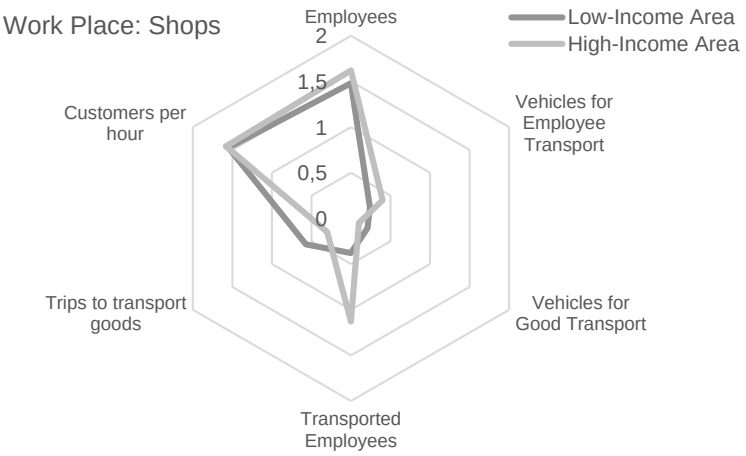
4 STUDY FINDINGS

4.1 General Travel Pattern

The subjects' characteristics in the collected sample were similar to the workplace surveys, yet this is not the case for the household survey (Table 4).

The family size in the LIA (5.71) is larger than in the HIA (3.99). Household members' trips conducted by private car in the high-income group outnumbered those of the low-income group. The opposite is true for pedestrian and PT trips. The employed household members are higher in the high-income group, while the unemployed members of the low-income group are higher. The average number of school students per household in the LIA is higher, but university students are fewer. The employability rate is higher in the high-income group of the workplace surveys (shops and offices). Although there are some differences between the number of employees, customers, and transport patterns between the two areas, it was not proven to be statistically significant (t-test results). In general, the employability rate is higher in the high-income group of the workplace surveys (shops and offices), with more trips being conducted. The differences in averages of the tested indicators, based on t-test results, were significant for the household survey, with one exception related to the number of university students, which was not statically significant. Contrarily, there were no significant differences in the indicators of the workplace survey (offices and shops).

Table 4 Survey's Subjects' Characteristics

Interview Place: Average Number of Trips Illustration	Indicators	T-test
	Residents: Family Size	t=6.875, p=0.000
	School Students	t=5.88, p=0.000
	Universities Students	t=-1.79, p=0.075
	Employees	t=-2.304, p=0.022
	Unemployed	t=6.383, p=0.000
	Private Car Users	t=-6.06, p=0.000
	Public Transport Users	t=6.36, p=0.000
	Pedestrian Trips	t=9.82, p=0.000
	Other Mode Users	t=-4.55, p=0.000
	Employees	t=-0.844, p=0.720
	Private Car Users	t=-0.887, p=0.385
	Public Transport Users	t=-1.193, p=0.26
	Pedestrian Trips	t=-0.845, p=0.437
	Other Mode Users	t=-0.138, p=0.892
	Entity Vehicles for employees' Transport	t=1.883, p=0.082
	Employees	t=-0.368, p=0.720
	Vehicles for Employee Transport	t=-0.795, p=0.429
	Vehicles for Good Transport	t=0.788, p=0.433
	Transported Employees	t=-2.139, p=0.038
	Trips to transport goods	t=0.671, p=0.505
	Customers per hour	t=-0.163, p=0.871

4.1.1 Trip Modal Split

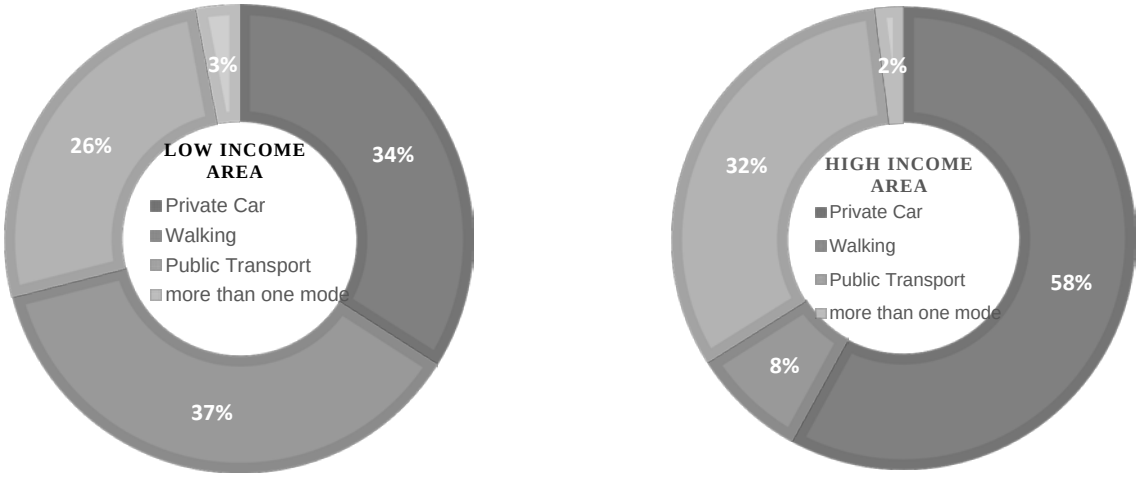
The trip modal split analysis showed the private car is the most common mode of transport for household members in the high income (61.1%), while walking is more common in the LIA (46.89%). The share of PT trips is similar regardless of the household income level. The retail and shop employees and owners in the HIA use their car (49.43%) or PT (37.93%) for mobility; the corresponding proportions in the LIA are 42.27% and 23.71%, respectively. In addition, one out of three shop owners and employees in the LIA walk to their workplace. More than 70% of office employees' trips are made by private car, and less than one-fourth use PT. Chi-square test results show a significant difference between trip modal choices due to the area type and income level (Table 5). In addition, one out of three shop owners and employees in the LIA walk to their workplace. More than 70% of office employees' trips are made

by private car, and less than one-fourth use PT. Chi-square test results show a significant difference between trip modal choices due to the neighbourhood income classification

The overall modal split, irrespective of the survey type and the interviewees' role, shows that private car is the most dominant mode of transport (58%) in the HIA, whereas walking is the most common mode of transportation (37%) in the LIA. The share of PT, including taxis, is almost identical.

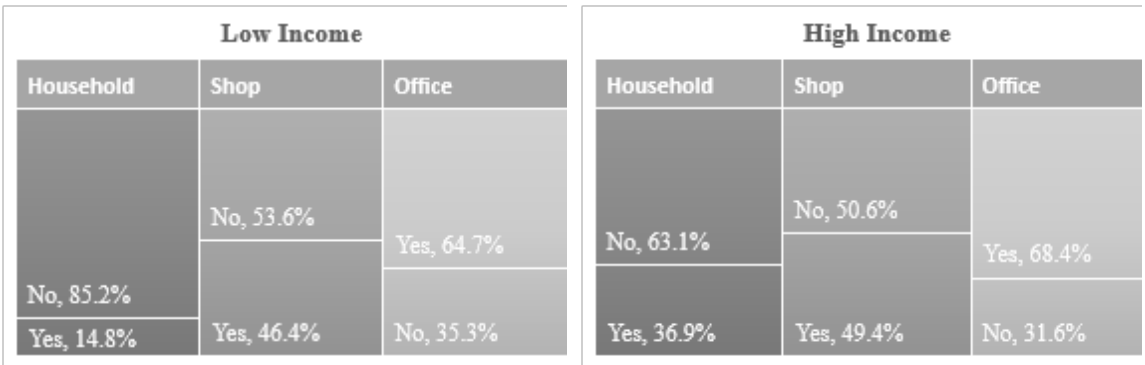
Table 5 Trip Modal Split by Area and Survey Types

Survey	Area Type	Private Car	Walking	PT	More than one Mode	Sample Size	Chi-Square Tests
Household	Low Income	19.33%	46.89%	29.78%	4.00%	450	χ^2=144.1, p=0.000
	High Income	61.09%	8.14%	28.05%	2.71%	221	
	Both Areas	33.08%	34.13%	29.21%	3.58%	671	
Shops	Low Income	42.27%	31.96%	23.71%	2.06%	97	χ^2=50.95, p=0.000
	High Income	49.43%	10.34%	37.93%	2.30%	87	
	Both Areas	45.65%	21.74%	30.43%	2.17%	184	
Offices	Low Income	73.53%	8.82%	17.65%		34	χ^2=9.53, p=0.049
	High Income	70.18%	5.26%	24.56%		57	
	Both Areas	71.43%	6.59%	21.98%		91	



4.1.2 Car ownership Level

The access to a private car determines the traveller modal choice. According to the household survey, one out of seven subjects own a car in the LIA compared to one out of three in the HIA, which is slightly more than double that of LIA (Fig.4).



	Household	Workplace: Shops	Workplace: Offices
Statistical Test	χ^2= 55.817, p=0.000	χ^2= 0.169, p=0.681	χ^2=0.133, p=0.715

Fig.4 Car ownership level of Survey Type and Income Level

The difference in the ownership levels is statistically significant due to the income level, which was not the case for the interviews made at the workplace, at either shops or offices. Car ownership level is higher for office employees (two out of three subjects own a car), and almost half of the shop owners and employees own a private car. On

average, there are 1.5 vehicles per household in the LIA compared to 1.9 vehicles for the HIA, and such a difference is insignificant (t=0.32, p=0.32). However, the quality of the vehicle differs, as the average age of the owned vehicle in the LIA is two-fold (12.5 years) that of the HIA (6.5 years) with a statistically significant difference.

4.1.3 Temporal Travel Demand

The interviewees were asked to report their perception on the demand for travelling. It was possible to select more than one option to answer this close-ended question, but not more than three options. The survey participants thought the travel demand was more pronounced in the evening and, to some extent, in the morning but not at noon or afternoon (Table 6).

Table 6 Temporal Travel Demand Pattern by Survey Type and Level of Income

Survey Type	Area Type	Morning	Noon	Afternoon	Evening	All but Evening	Morning & Evening	All but Morning	All period	Sample Size
General (Pilot)	LIA	26.8%	4.9%	12.2%	14.6%	12.2%	14.6%	4.9%	9.8%	41
	HIA	1.9%	9.6%	13.5%	13.5%	17.3%	19.2%	13.5%	11.5%	52
	Both Areas	12.9%	7.5%	12.9%	14.0%	15.1%	17.2%	9.7%	10.8%	93
Household	LIA	17.4%	11.6%	7.4%	23.1%	9.1%	19.0%	11.6%	0.8%	121
	HIA	30.1%	4.1%	0.0%	8.2%	26.0%	12.3%	9.6%	9.6%	73
	Both Areas	22.2%	8.8%	4.6%	17.5%	15.5%	16.5%	10.8%	4.1%	194
Office	LIA	30.0%					40.0%	0.0%	30.0%	10
	HIA	21.4%					35.7%	14.3%	28.6%	14
	Both Areas	25.0%					37.5%	8.3%	29.2%	24
Shops	LIA	4.3%	4.3%	6.4%	8.5%		74.5%	2.1%		47
	HIA	16.7%	10.%	0.0%	26.7%		30.0%	16.7%		30
	Both Areas	9.1%	6.5%	3.9%	15.6%		57.1%	7.8%		77

The general survey, which was a road-side interview reflecting all sorts of activities, indicates a high demand in the morning of the LIA; the demand is high in the evening of the HIA, although the statistical test failed to show that there is a significant difference between the answers from the two neighbourhoods (χ^2=16.927, p=0.152). The household members of the LIA tend to travel more in the evening (beyond 17:00), while the demand for travelling in the HIA is higher in the morning. The difference between travel demand patterns in the time of travel for the household survey shows a significant difference between the two neighbourhoods (χ^2=62.34, p=0.000). Unlike workplace surveys, the responses in the general and household surveys spread over many answers. The demand for shopping in both surveyed areas has two peaks, one in the morning and one in the evening. Some shoppers prefer to shop only in the evening in the HIA (26.7%) compared only to 8.2% for the shopper in the LIA. The statistical analysis showed a significant difference in shopping travel demand patterns (χ^2=25.03, p=0.000). The employees in offices select fewer answers, and almost one-third of the responses showed a perception of demand at any time. However, most employees perceive two peak demand peaks (morning and afternoon). The difference between the temporal demand for this group of interviewees was found statistically insignificant (χ^2=1.63, p=0.8) due to income.

4.1.4 Some Indicators of Transportation Modes

The analysis looked into some indicators for the transportation modes, which may explain the prevailing travel pattern in the study area.

Road Crash

The survey participants were expected to shed light on their involvement in road crashes during their driving experience. Table 7 shows that almost one-third of the households were involved in road crashes that were mainly collisions and resulted in property damage only (PDO).

Few crashes (13.3) in the HIA were pedestrians, and none were reported in the LIA. Fatal crashes compose 3.6% and 6.7% of the LIA and HIA, respectively, indicating a high level of risk in the HIA. The statistical analysis showed no significant difference in the subject's crash involvement or the crash consequences due to the income group (area), which is not the case for road crash types that show statistically evident significant differences between the two neighbourhoods.

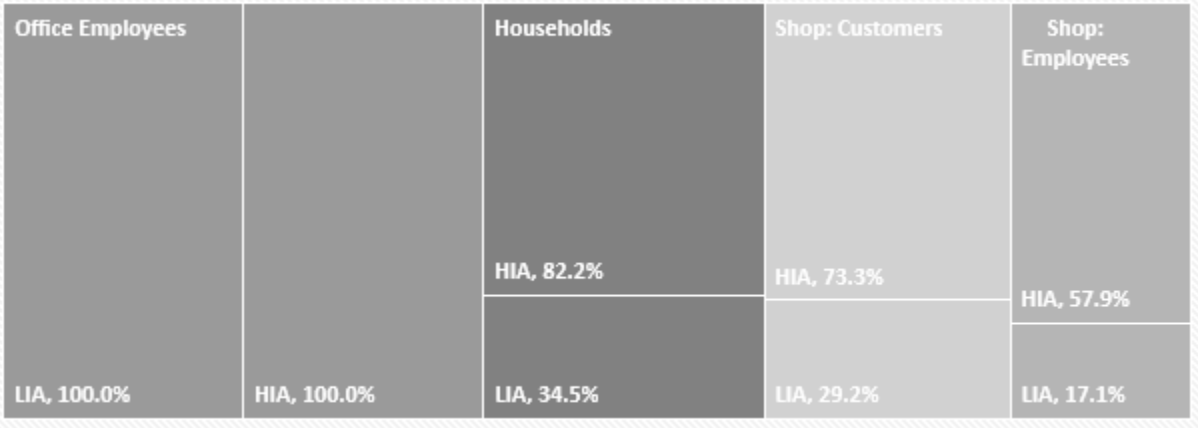
Table 7 Participants' Road Crash Experience by Survey Types

Survey Time	Area	Crash Involvement		Crash Types			Crash Consequences			Crashes #
		Involve in crash	not Involved	Collision	Pedestrian	Turnover	Fatal	Injury	PDO	
Households	LIA	36.6%	63.4%	100.0%	0%	0%	3.6%	7.1%	89.3%	34
	HIA	30.3%	69.7%	86.7%	13.3%	0%	6.7%	6.7%	86.7%	30
Statistical Test		χ^2=0.845. p=0.358		χ^2=4.01, p=0.0452			χ^2=0.447, p=0.7998			
Office	LIA	52.2%	47.8%	91.7%	8.3%	0%	8.3%	16.7%	75.0%	12
	HIA	38.7%	61.3%	75.0%	16.7%	8.3%	8.3%	16.7%	75.0%	12
Statistical Test		χ^2=0.969, p=0.325		χ^2=1.53, p=0.464			χ^2=0.0, p=1.0			
Shops	LIA	59.1%	40.9%	92.0%	4.0%	4.0%	0%	8.0%	92.0%	26
	HIA	62.3%	37.7%	92.1%	5.3%	2.6%	7.9%	26.3%	65.8%	38
Statistical Test		χ^2=0.11, p=0.7398		χ^2=0.14, p=0.93			χ^2=5.99, p=0.05			

The participants in the retail sector (shops) had the highest involvement in road crashes among other surveys, mainly collisions (92% in both areas). Still, other crashes were also reported, a small proportion though. Around one-fourth of crash involvement in HIA lead to injuries and 7.9% to fatality crash. The corresponding ratio for the LIA is 8% for injuries and no fatalities being recorded. Involvement in pedestrian crashes was the highest among office employees (16.7%), and some (8.3%) were involved in turnover crashes, leaving the proportion of collisions down to 75%. Crash experience for office employees showed the crashes were severe, with 8.3 and 16.7% fatal and injury crashes, respectively. The crash indicators for the office and shop survey participants were statistically indifferent, as indicated by χ^2 test results.

Parking Spot Availability

Fig.5 shows that less than 30% of the LIA shops have a garage (parking spots) within the premises as reported by their customers, which may explain why the owners and the employee are parking on-street, as defined in section 4.2.2. On the other hand, 73.3% of the shops in the HIA have a garage within their premises, which describe the low proportion of their employees doing on-street parking. In the household survey, around two-thirds of the subjects in the LIA do not have any parking spots within their properties. In contrast, more than 80% of the households in the HIA have one. The statistical tests in the three surveys provide evidence of a significant difference in garage availability due to the income level of the surveyed area (Chi-square test results, Fig.5). All participants in the study area office survey indicated they had access to a parking spot; still, the office employees who provided for this aspect in the survey were small, and it would be hard to generalize this finding.



	Household	Workplace: Offices	Workplace: Shops	Shop Customer Survey
Statistical Test	χ^2= 41.3, *p=0*.000	N.A	χ^2=14.49, p=0.000	χ^2=10.26 p=0.001

Fig.5 Proportion of Subjects Having Parking Spots

Hourly Traffic Variation and Congestion

Based on the participants' reflections, which would always influence their trip planning and associated decisions, in the study's surveys, the morning peak traffic conditions are perceived to be at (7:00). Still, it has not perceived as the highest in the daytime by the households, who believe that the afternoon peak at 13:00 and 16:00 for the HIA and

LIA, is the period witnesses high level of congestions (Table 8). The employee surveys, depicting the trip attraction, refer to the morning peak as the busiest hour of the day, while the afternoon peak is perceived to be at 13:00 and 16:00 for the office and shop survey, respectively. Table 7 suggests that while the participants in the office surveys were firm in defining distinctive peaks, this was not the case for the household and shop survey, particularly in the LIA. Chi-square test results showed a statistically significant difference in defining the peak hour for the household and shop surveys but the office, where the results did not show a significant difference between the perception of the participants from the two neighbourhoods.

Table 8 The Participants' Perception of Peak Hour by Survey Type.

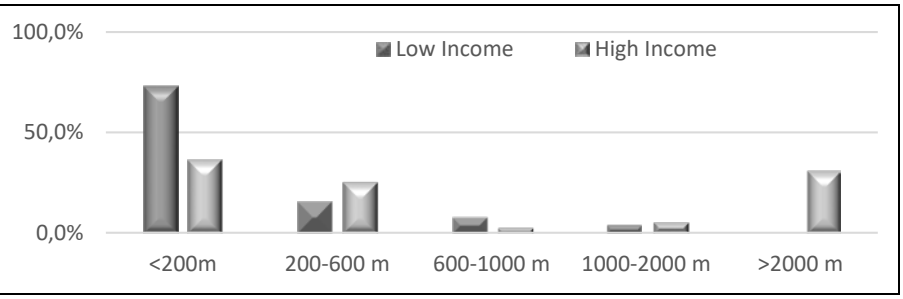
Survey	Area	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	Statistical Test R
Household	LIA	*19.0%*	2.5%	2.5%	6.6%	0.0%	0.8%	17.4%	11.6%	7.4%	23.1%	1.7%	7.4%	χ^2=65.21, p=0.00
	HIA	*13.0%*	0.0%	10.1 %	0.0%	0.0%	4.3%	31.9%	4.3%	0.0%	8.7%	24.6%	2.9%	
office	LIA	40.0%	0.0%	0.0%	0.0%	0.0%	*30.0 %*	*30.0%*	0.0%	0.0%	0.0%	0.0%	0.0%	χ^2=1.633, p=0.803
	HIA	35.7%	0.0%	7.1%	0.0%	7.1%	*28.6 %*	21.4%	0.0%	0.0%	0.0%	0.0%	0.0%	
Shop	LIA	74.5%	0.0%	0.0%	2.1%	0.0%	0.0%	4.3%	4.3%	6.4%	8.5%	0.0%	0.0%	χ^2=25.03, p=0.0015
	HIA	30.0%	0.0%	6.7%	6.7%	0.0%	0.0%	10.0%	3.3%	0.0%	*26.7%*	13.3%	0.0%	

Walking Trips Characteristics

The general survey showed the average walking distance in the study area is 716 meters for trips produced or attracted, corresponding to 12 minutes of walking (Table 9). The interviewed subjects in the HIA walked more than one kilometre (17 minutes) compared to only 290 meters in LIA (4.8 minutes). A statistically significant difference in walking distance due to area type (χ2= 13.452, p=0.009) can be explained by the difference in the area layout, the land use, and spatial distribution of activities of the HIA that may lead to a longer walking distance.

Table 9 Household Walking Distance by Area Level of Income-one-way Trip

Area Income Level	Average (m)	Sample Size
Low Income	290	26
High Income	1,023	36
Both Areas	716	62



Public Transport Service

The share of different types of PT services presented in Table 10 shows some agreement between the results provided by the general and the household surveys that aimed at exploring the trip production characteristics. The similarities between the modal share of PT services for workplace surveys (Shops and offices) are less pronounced. In the low-income area, white taxis (shared taxis) are the most common PT type, while yellow taxis are used more in the HIA; except for the office employees, the share of yellow taxis exceeds 50% in the three surveys. Oppositely, the white taxi share of public transport trips in LIA exceeds 50% in the general, office, and household surveys and even reaches up to 73.9% for shop the survey (trip attraction survey). The share of PT service is higher for the employees in the retail, while its share in the household survey does not exceed 23.1%, which is similar to the shop and general surveys. More than fifty percent of all working trips to offices are made by buses. The proportion of bus trips for shop owners and employees varies by income level; the share in the LIA is only 26%, while it is 42.4% for the HIA, indicating an association between PT mode share and income level. The modal spilt of the public transport service varies and is proven to be statistically significant tested at a two-tailed 5% significant level (chi-square test).

Table 10 PT Service Mode By Survey Type and Income Level

Area Income Level	General Survey			Household			Office			Shops		
	Bus	White Taxi	Yellow Taxi	Bus	White Taxi	Taxi	Bus	White Taxi	Yellow Taxi	Bus	White taxi	Taxi
Low Income	25.1%	50.1%	25.1%	23.1%	53.8%	23.1%	50.0%	50.0%	0.0%	26.1%	73.9%	0.0%
High Income	26.6%	23.3%	50.0%	26.7%	23.3%	50.0%	57.1%	0.0%	42.9%	42.4%	0.0%	57.6%

Area Income Level	General Survey			Household			Office			Shops		
	Bus	White Taxi	Yellow Taxi	Bus	White Taxi	Taxi	Bus	White Taxi	Yellow Taxi	Bus	White taxi	Taxi
Both Areas	25.8%	37.1%	37.1%	24.4%	43.2%	32.5%	55.0%	15.0%	30.0%	35.7%	30.4%	33.9%
Test-Results	χ^2=26.63, p=0.000			χ^2=26.63, p=0.000			χ^2=41.0, p=0.000			χ^2=10.48, p=0.015		

The subjects, who participated in the study, were also asked if the PT services have adequate temporal availability. The subject responses proved to be statistically different due to the type of survey and subject income level (Table 11). For instance, the reactions in the household survey showed that buses in the LIA operate for long hours during the day, followed by white taxis. The household responses of the HIA suggest the availability of yellow taxis around the clock. The workplace survey responses of the LIA indicated that white taxi availability out-rate the bus availability or yellow cabs, which was not mentioned in the answers of the shop owners and employees in the HIA who believed that only yellow taxis are available around the clock. The participants in the three surveys have different perspectives due to their income group level, as shown below by the chi-square test results (p<<0.001).

Table 11 PT Service Availability by Type of Survey and Income Level

Survey	Household			Office			Shop		
Area Type	Bus	White Taxi	Yellow Taxi	Bus	White Taxi	Yellow Taxi	Bus	White Taxi	Yellow Taxi
Low Income	67.4%	27.3%	5.3%	25.0%	70.8%	4.2%	16.7%	83.3%	0.0%
High Income	7.5%	0.0%	92.5%	0.0%	0.0%	100.0%	0.0%	0.0%	100.0%
Both Area	50.3%	19.5%	30.3%	11.3%	32.1%	56.6%	5.0%	25.0%	70.0%
Statistical Test	χ^2= 143.87, p=0.000			χ^2= 50.1, p= 0.000			χ^2= 20.0, p=0.00		

4.2 Travel Pattern by Survey Type

4.2.1 Household Trip Pattern Analysis

The household trips will be analysed by their frequency, duration, purpose and temporal variation.

Trip Numbers and Variations

The average number of trips per household for all its members is 4.65 per day in both areas (Table 12). Families in the LIA made more trips (5.14) than the HIA (3.71), and the difference is statistically significant. On average, two trips per person are made by private car compared to 1.8 walking trips. The difference in the average number of trips made by walking or personal car is not statistically significant due to income. Unlike other types of trips, the number of PT trips in the LIA is lower than in the HIA, and the difference was proven to be statistically significant. The subjects consider taxis a public transport mode, which may explain the high number of PT trips in the HIA. Further, there is a high variation in the number of trips of LIAs; irrespective of the transport mode in use, the trip pattern is more consistent in the HIA, particularly for the PT trips. The F-test results that examined the difference in the variation showed a significant difference between the two groups for all trip indicators but not the walking trips.

Table 12 Average Household Trip and Variation by Mode and Type of Area and Statistical Tests Results

Trip Type	Area Type (Income level)	N	Mean	Std. Deviation	F-value	Sig.	t-value	Sig. (2-tailed)
Personal Car	Low Income	100	2.09	1.3933	53.017	0.000	0.748	0.456
	High Income	138	1.986	0.120				
Walking	Low Income	282	1.784	0.658	1.180	0.278	0.149	0.882
	High Income	21	1.762	0.436				
PT	Low Income	143	1.636	0.600	214.343	0.000	-7.249	0.000
	High Income	64	2.000	0.000				
Average No. of Trips per Person	Low Income	444	2.180	1.204	72.465	0.000	2.629	0.009
	High Income	218	2.010	0.339				
Average No. of Trips per household	Low Income	123	5.140	2.709	17.52	0.000	4.82	0.000
	High Income	67	3.710	1.622				

Travel Time

Travel time of a low-income household member on trips made by private car or walking is longer than HIA. The average travel time regardless of the neighbourhoods where the activity took place, by car is 27.6 minutes, and 22.2 minutes for walking trips. Table 7 suggests that residents in the study area walk for two kilometers (assuming the average pedestrian speed of 5 km/h). Table 7 shows that almost half of the participants in the HIA use their car for short trips (<15 minutes), while a similar proportion of car users in the LIA travel longer (15-30 minutes). Although the data indicate differences in personal car travel time, it is not statistically significant. Pedestrians in the LIA walk more and longer than in the HIA, where one out of seven pedestrians could walk for more than one hour.

Nevertheless, the difference between the two areas of different income is statistically insignificant. PT trip travel time, on average, is 25.7 minutes with no significant difference in area type. It seems that people in the study area do not spend a long time travelling, as more than 60% of trips are less than 30 minutes. However, thirty percent of travel made by private car by the resident of the LIA could be in the range of 46-60 minutes, which is also the expected travel time of three out of ten PT trips made by the resident of the HIA. Table 13 suggests that PT is efficient, where half of the subjects could complete one directional trip in less than 15 minutes. The difference between the average PT travel time in the two neighbourhoods is minimal (0.3 minutes) and statistically insignificant.

Table 13 One-Directional Trip Travel Time Characteristics by Transport Mode and Area Type (Minutes)

Transport Mode	Area Type	Subjects	<15 min	15-30 min	31-45 min	46-60 min	>60 min	Average (min)	χ^2
Personal Private Car	Low Income	106	15.00%	45.00%	10.00%	30.00%		31.5	χ^2=5.21 p=0.157
	High Income	141	47.06%	29.41%	11.76%	11.76%		23.1	
	Both Areas	247	29.73%	37.84%	10.81%	21.62%		27.6	
Walking	Low Income	286	32.73%	21.82%	3.64%	25.45%	16.36%	23.7	χ^2=6.49 p=0.165
	High Income	21	45.71%	28.57%	8.57%	8.57%	8.57%	19.9	
	Both Areas	307	37.78%	24.44%	5.56%	18.89%	13.33%	22.2	
PT	Low Income	155	46.15%	25.64%	7.69%	17.95%	2.56%	25.8	χ^2=3.29 p=0.51
	High Income	65	48%	24.00%	0.00%	28%	0.00%	26.1	
	Both Areas	220	46.88%	25.00%	4.69%	21.88%	1.56%	25.9	

Trip Purpose

Education followed by work is the primary purpose of household members' travel (Fig.6). The LIA trips for education purposes are higher than the HIA, and the opposite is valid for work trips. Other trips account for 14.4% and 12.4% of all travel purposes for low-income and HIAs, respectively. Shopping trips account only for less than 5% of all trips in the study area (3.8% for LIA and 4.8% for HIA). Although there are some different patterns in the purpose of travelling due to participant income, still, there was no proof of a significant statistical difference (χ^2= 10.163, p=0.071).

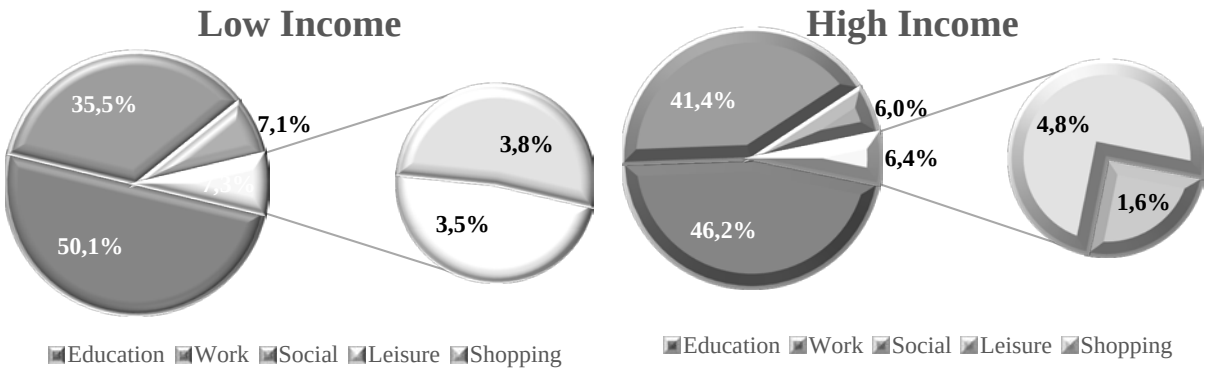
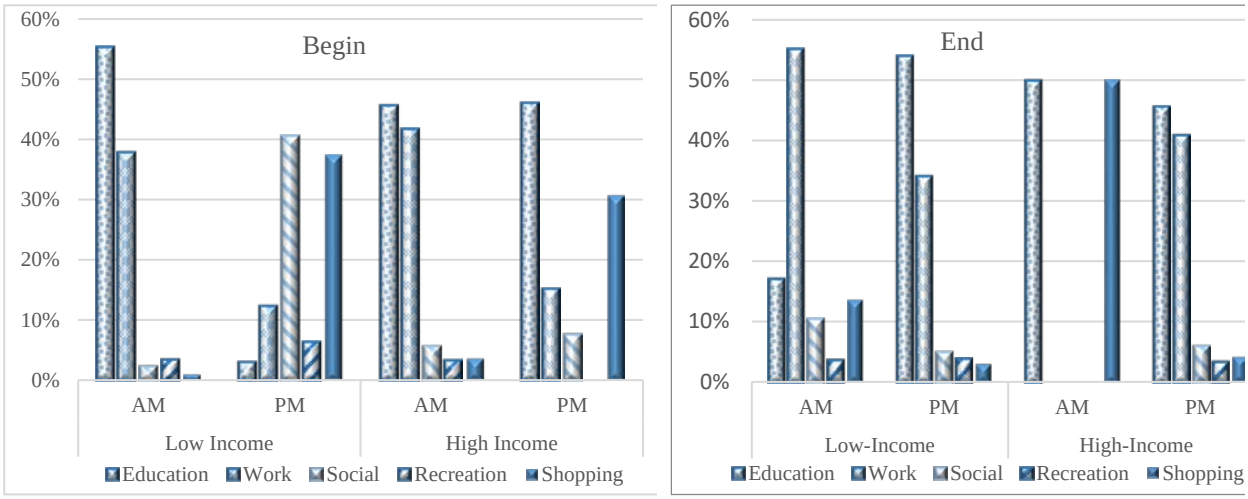


Fig.6 Households' Member Travel Trip Purpose by Level of Income

Trip Temporal Variation and Purpose

The trips were grouped by purpose and the period when they were either beginning or ending, considering two periods, before (AM) and afternoon (PM). Many morning trips begin in the LIA either for work or education. In contrast, they are fewer in the afternoon for shopping or socializing. In the HIA, 87% of trips made in the morning are for work or education. Unlike the LIA trip purpose patterns, almost half of the trips started in the afternoon are for education purposes (Fig.7). A high proportion of morning trips that end in the LIA are working trips, while more than half of the trips that end in the afternoon in this area are educational trips. In the HIA, very few trips end in the morning (less

than 10) for education and shopping purposes. In the afternoon, half of the trips completed in this area are for educational purposes, and the remaining are distributed almost evenly among the other four trip purposes of travelling. The statistical analysis for the two neighbourhoods showed significant differences between travel purposes due to the trip's beginning or ending time, which is also valid for both studied areas.

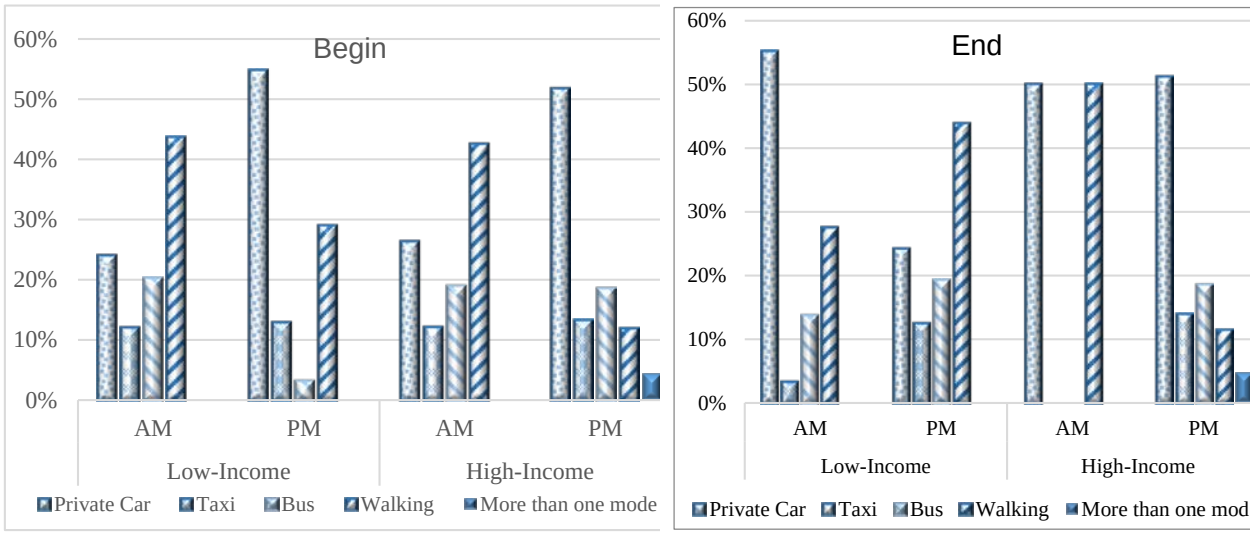


χ2=204.004, p=0.001 χ^2=20.605, P=0.0001 χ^2=21.595, p=0.006 χ^2=18.317, p=0.001

Fig.7 Trip Purpose by Start and End Period and the Income Level

Trip Temporal Variation and Modal Split

Trip modal split differs by travelling period, as shown in Fig.8. In the LIA, 44% of all trips started in the morning are pedestrian trips, mainly because they are walking to school trips, while the corresponding proportion in the afternoon is 30%. Besides, 55% of trips that begin in the afternoon are made by private car, which is more likely related to social and shopping purposes. A similar trend of trip distribution by transport mode was observed for the HIA, except for afternoon pedestrian trips, which do not exceed 12%. In contrast, the proportion of trips beginning in the afternoon made by personal car is double the corresponding proportion of trips starting the in the morning. Private car use in the LIA accounts for 55% of trips that ended in the morning, while pedestrian trips account for 28%. The proportion of pedestrian trips in the afternoon increased to 44%, almost the same ratio that began in the morning, mainly coming back from school. In comparison, private car use was reduced to 24%, indicating that only half of the trips begin the LIA terminated and the remaining are going elsewhere. The morning trips or end in HIA are conducted equally by private car or walking, reflecting their nature as education (walking trips) and working (Personal vehicle). In the afternoon, 51% of trips were made by personal vehicles, followed by buses (18%) and then taxis (14%); the difference is marginal. The selection of transport mode for trips beginning or ending in the morning is statistically different from the subjects' selection of the transport mode for the afternoon in the LIA but not for the HIA, as indicated by χ^2 results that tested a significant level of 5%.

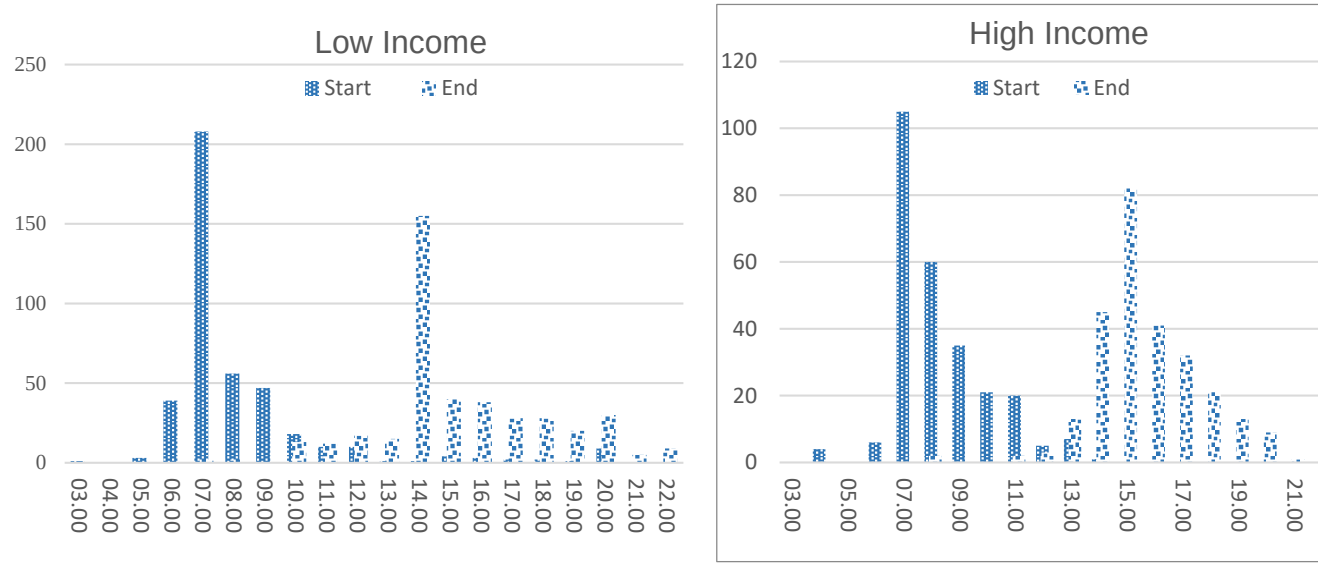


χ^2=16.097, p=0.001 χ^2=1.764, p=0.779 χ^2=20.975, p=0.002 χ^2=6.238, p=0.182

Fig.8 Trip Modal Split by Start and End Period and the Income Level

Hourly Trip Variation

Few trips end in the morning or start in the afternoon, whereas a high number of trips begin in the morning or end in the afternoon, indicating that both areas produce rather than attract trips (Fig.9) and the afternoon trips ending in the study area are return to home trips.



χ^2=415, p=0.000 χ^2=264, p=0.000

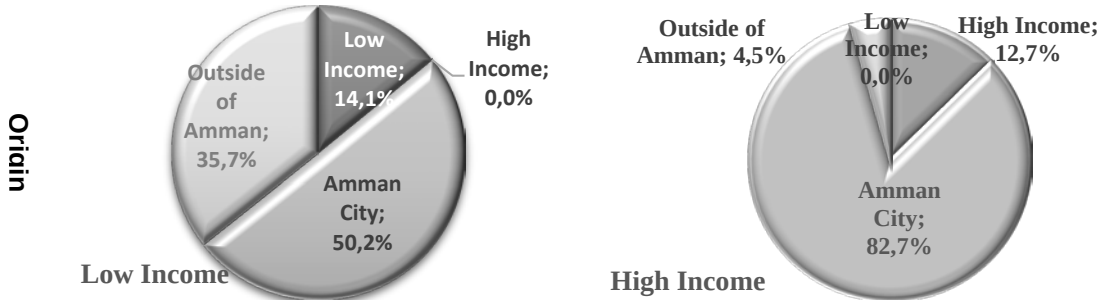
Fig.9 Hourly Trip Demand Variation by Area Type

The morning peak of all trips starting was around seven, and it was around two in the afternoon for trips ending in the LIA, when people return home. Off-peak travel demand is minimal and the almost flat. In the HIA, the trips' peak was still at seven in the morning for the originating trips and three in the afternoon for trips ending there. The off-peak demand is gradually reduced for both ways of travelling (beginning or ending), later on it starts to diminishe. Most subjects in both areas start their travel to work between eight and nine in the morning with 90% and 93% for LIA and HIA, respectively. One-third of the employees in the LIA continues to work until late hours in the evening (30%), while one-fourth of the employees in HIA finish work before 16:00. Still, most of the employees (70%) complete their work between 16:00-20:00. However, there is no statistical difference in the working start time (χ^2=0.038, p=0.846) or ends (χ^2= 3.930, p=0.269) due to the level of income in the area.

4.2.2 Workplace Trip Pattern Analysis

Trip origin and Purpose

The workplace visitors' survey showed that a small proportion of the trips of subjects started in the two neighbourhoods (10.2% and 3.5% in the LIA and HIA, respectively). Most of the visitors came from other parts of Amman, particularly to the HIA (Fig.10). Around one-third of the subjects visiting the LIA came from outside Amman. The corresponding proportion in the high-income group is tiny (less than 5%). Internal trips account for only 14.1% and 12.7 of the LIA and HIA, respectively. The trip origin distribution in the LIA is significantly different from the HIA(χ^2=95.424, p=0.000).



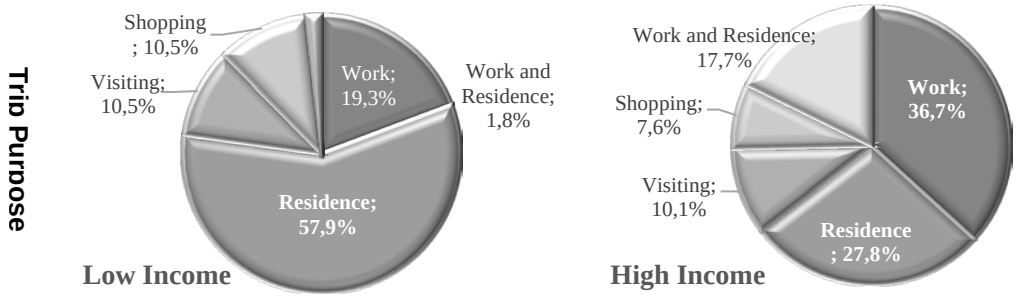


Fig.10 The Purpose and Destination of Trips Originated in the Study Area

The interviewed workplace visitors to the LIA's general survey primarily reside in the same area (57.9%), double the HIA's proportion (27.8%). The HIA provide work opportunities for 36.7% of the peoples ending their trip there, which is also double what the LIA would offer (19.3%). Moreover, one in six interviewed persons is working and residing in the HIA compared to one out of 55 people in the LIA. Other purposes, but less frequent, include visiting and shopping. Overall, there is a significant difference in the trip purpose due to neighbourhood people's economic status (χ^2=95.424, p=0.000).

Trip Travel Time

A sample of travellers in both neighbourhoods consisting of 76 participants, more in the HIA, showed they spent more than two and half hours daily traveling for all sorts of purposes; the average daily time spent on travelling ranges between 153.6 and 155 minutes for LIA and HIA, respectively, with no proof of any significant difference between the two areas (χ^2=3.591, p=0.46). Few spent less than one hour in their daily mobility in the LIA (3.8%), but none in the HIA. Two-thirds of the participants in the two areas travel up to three hours in their daily mobility. Table 8 shows that more than 70% of work trips take less than half an hour and the average one-directional trip travel time for work in the office is 30.2 compared to 20.1 minutes for work in retail sectors, which is two minutes more than the time needed for the shopper to travel (Table 14). The difference between the travel time for office work between the two neighbourhoods is marginal (less than one minute), and the same applies to the participant's travel time for shopping; the statistical test proved that such a difference is insignificant, as indicated by χ^2 test results. On the other hand, the difference in one-directional trips for the employees in the retail sector is statistically significant (17.9 and 22.5 minutes for LIA and HIA, respectively).

Table 14 Travel Time for Working Places by Area Level of Income.

Time (minute)	One-way-Trip Travel Time for Working Place									Time (minute)	Time of Daily Trips for All Purposes		
	Office			Shop: Employee			Shop: Customers						
	LIA	HIA	Both Areas	LIA	HIA	Both Areas	LIA	HIA	Both Areas		LIA	HIA	Both Areas
<15 min	41.2%	33.3%	36.3%	58.8%	50.6%	54.9%	48.1%	56.0%	51.9%	<60 min	3.8%	0.0%	1.3%
15-30	32.4%	33.3%	33.0%	30.9%	28.7%	29.9%	48.1%	36.0%	42.3%	60-120	42.3%	44.0%	43.4%
30-45	0.0%	1.8%	1.1%	10.3%	9.2%	9.8%	0.0%	8.0%	3.8%	121-180	23.1%	32.0%	28.9%
45-60	11.8%	22.8%	18.7%	0.0%	9.2%	4.3%	3.7%	0.0%	1.9%	181-300	19.2%	10.0%	13.2%
>60	14.7%	8.8%	11.0%	0.0%	2.3%	1.1%				>300	11.5%	14.0%	13.2%
Sample Size	34	57	91	97	87	184	27	25	52		26	50	76
Average (min)	29.4	30.7	30.2	17.9	22.5	20.1	18.56	17.82	18.20		155	153.6	154.3
Statistics	χ^2=3.036, p=0.552			χ^2=11.842, p=0.0185			χ^2=3.693, p=0.297				χ^2=3.591, p=0.46		

Vehicle Parking Location

Parking is a challenge that the people in Amman and other cities worldwide face. In this study, the participants were asked to indicate if they parked their vehicles on or off the streets. The shop owners and employees in LIA tend to park on-street (85.7%) next to their shops, while their peers in the HIA use off-street parking instead (81.9%). The statistical analysis showed a significant difference between the two areas (χ^2=43.502, p=0.00). Most shop customers, irrespective of the area level of income, use on-street parking (Fig.11). The proportion is slightly higher in the HIA (87.5%) than in the LIA (83.3%). Still, the statistical test failed to show any significant difference between the two areas (χ^2=1.02, p=0.60). The chaotic on-street parking often associated with double and sometimes triple parking adds to the congestion.

Fig.11 Workplace Employees and Visitors Parking Location by Income Level.

In both areas, the proportion of office employees who use off-street parking is three folds those who use on-street parking, which may attribute to the long working hours and the employees tend to park their vehicles away from traffic safely. However, that does not imply that the off-street parking is well designed, constructed, and regulated as, most likely, the parking yard would be unpaved, and man operated. The statistical test showed a significant difference in the proportions of one and off-street, two-tailed tests at a 5% confidence level (χ^2=6.616, p=0.036).

Table 15 shows that many office employees in both neighbourhoods walk less than five minutes from parking their vehicles to the workplace. (72.3 and 61.5% for the LIA and HIA, respectively). A similar proportion was reported for the shop employees in the LIA, which significantly differed from the HIA's corresponding ratio (16.7%). More than 80% of the shop employees in the HIA walk more than five and less than 10 minutes. Overall, the employees of shops and offices in the HIA walk longer than in the LIA. The difference in time is more pronounced for the shop owners and employees (7.3 minutes- 500 meters in HIA compared to 5.8 minutes-350 meters in the LIA) and is statically significant (χ^2==20.770, p=0.000). The difference is marginal for office employees (4.8 minutes, 300 meters for LIA compared to 5.5 minutes-330 meters for HIA), and the difference was found to be statistically insignificant (χ^2=1.563, p=0.458).

Table 15 Distance from parking Spot to Workplace by Area Level of Income (min)

	Offices			Shops		
Walking Time	Low Income	High Income	Both Areas	Low Income	High Income	Both Areas
<5min	72.7%	61.5%	65.6%	63.9%	16.7%	40.3%
5-10min	27.3%	33.3%	31.1%	30.6%	83.3%	56.9%
>10m min	0.0%	5.1%	3.3%	5.6%	0.0%	2.8%
Sample Size	22	39	61	36	36	72
Average	4.8	5.5	5.2	5.83	7.33	6.58
		χ^2=1.563, p=0.458			χ^2=20.770, p=0.000	

Shoppers walk or travel by car, then walk to their shopping place. Table 16 suggests, on average, people walking distance to the shopping place would be 212 (3.5 minutes); the length in the LIA (323 meters, 5.4 minutes of walking) is longer than the distance in the HIA (96 meters, 1.6 minutes of walking). If they use a private car, they will walk a shorter distance from the parking spot to the shopping place. On average, they walk for 59 m in the LIA and 29 m in the HIA (less than a minute), which supports the previous not on-street parking and chaotic behaviour of double parking to do the minimal walking to the destination. The statistical analysis showed the difference in distance due to area income level is significant (χ^2=10.69, p=0.014).

Table 16 Shoppers' Walking Distance to Shopping Place (meter)

Attribute	Area Income Level	<100m	100-200 m	200-600 m	600-1000 m	>1000 m	Sample Size	Average meter	Statistical Test
	Low Income	53.8%	11.5%	11.5%	11.5%	11.5%	26	323	χ^2=8.96

Attribute	Area Income Level	<100m	100-200 m	200-600 m	600-1000 m	>1000 m	Sample Size	Average meter	Statistical Test
Distance of walking along trip(m)	High Income	88.0%	4.0%	8.0%	0.0%	0.0%	25	96	p=0.062
	Both Areas	70.6%	7.8%	9.8%	5.9%	5.9%	51	212	
		<20m	20-60	100-200	>200				
Distance of walking from car to shop(m)	Low Income	45.5%	27.3%	27.3%	0.0%		11	59	χ^2=10.69 p=0.014
	High Income	87.5%	8.3%	0.0%	4.2%		24	29	
	Both Areas	74.3%	14.3%	8.6%	2.9%		35	38	

4.3 Trip Generation Modes

Several models were developed to predict the number of generated trips for different trip purposes or types to analyse the travel pattern further. The neighborhood's variable reflecting residents' income was integrated into the models as a dummy variable to measure its impact on the generated tips, where the HIA is the reference level. The neighbourhood's variable was retained in models, even if its coefficient was not statistically different from zero. The likelihood ratio chi-square was used to test the goodness of fit of generalized linear models. The Wald Chi-Squared test was used in the model parameters testing. If the parameters of explanatory variables differ from zero, they should be retained in the model or removed from the model if equal to zero at the defined significant level (0.05). Pearson correlation coefficient (r) was used to assess the model prediction power by relating modelled values to the observed value; the higher its value is, the higher the model prediction power is (Table 17).

The trip production models- household based- were developed for each mode of transport, i.e., the daily trip produced by personal private car (model 1), and so on for walking trips (model 2). Two models were developed for all daily trips produced by a household regardless of the mode of transport in use (Models 4 and 5). Two models for trips attraction -office work paced based and three models – shop work-based models were constructed to predict attracted daily trips irrespective of the mode of transport in use. The difference between these models is the predictor variable and the inclusion of the dummy variable in some models (model numbers 7, 9, and 10).

Many variables were explored in the modelling process, but very few have proven valid predictors, which vary according to the trip-based type. For instance, the household trips' production is a function of the number of residents, schools, and university students, and employed household members. To some extent, the explanatory variables differ according to the mode of transport in use. The number of trips made by private cars can be explained by the number of students in the university and the number of household members who have jobs. The number of trips in LIA is less than the HIA by 0.95, which is statistically significant. The association between the predicted trips conducted by private cars and the observed number is moderate (r=48.1%). The number of university students can predict household-produced trips using public transport. The PT trips in the LIA are higher than the HIA by 1.13 trips. The correlation between the predicted and observed PT trips is 49%, which is moderate, like the private car trips. Despite their low prediction powers, these two models were included in the table to illustrate the variables that impact these types of trips. However, it should be noted that such a low prediction power might be enhanced if other variables are included, if available. On the other hand, the number of school students explains the household walking trips with adequate prediction power (73.6%), which is higher than that of the private car or the PT. Walking trips in LIA, on average, outnumber that of the HIA by 1.27.

Table 17 Statistical Models and Significance

Trip Based Type	Model #	Statistical Models	Statistical Test	R predicted- observed Modelled
Household	1	$Car\ Trips = 1.343 + 0.27x_2 + 033x_3 - 0.95x_5$ (χ_c^2=37.64, p_c=0.00) (χ_2^2=7.46, p_2=0.006) (χ_3^2=10.16, p_3=0.01) (χ_5^2=27.78, p_5=0.00)	χ^2=51.22, p=0.00	48.1%
	2	$Walking\ Trips = -1.13 + 0.28x_1 + 1.27x_5$ (χ_c^2=36.7, p_c=0.000) (χ_1^2=85.6, p_1=0.00) (χ_5^2=40.35 p_5=0.00)	χ^2=221.7, p=0.00	73.6%
	3	$PT\ trips = -0.931 + 0.315x_2 + 1.13x_5$ (χ_c^2=24.07, p_c=0.000) (χ_2^2=30.41, p_2=0.00) (χ_5^2=41.31 p_5=0.00)	χ^2=70.19, p=0.00	49%
	4	$All\ Trips = 0.37 + 0.824x_4 + 0.104x_5$ (χ_c^2=1.34, p_c=0.248) (χ_4^2=170.5, p_4=0.000) (χ_5^2=0.143, p_5=0.705)	χ^2=140.4, p=0.00	71.5%

Trip Based Type	Model #	Statistical Models	Statistical Test	R predicted- observed Modelled
	5	$All\ Trips = 0.85 + 0.16x_1 + 0.18x_2 + 0.09x_3 + 0.17x_5$ (χ_0^2=72.16, p_0=0.001) (χ_1^2=62.5, p_1=0.00) (χ_2^2=25.86, p_2=0.02) (χ_3^2=5.15, p_3=0.00) (χ_5^2=4.49, p_5=0.034)	χ^2=97.5, p=0.00	64.2%
		C: intercept; X_1;Number of Students in the Schools; X_2: Number of students in the universities; X_3: Number of employed household members; X_4: Number of residents; X_5: Area Type (neighbourhood income level)		
Workplace: Office	6	$All\ Trips_1 = -0.194 + 1.0x_1$ (χ_c^2=0.87, p_c=0.35) (χ_1^2=1640, p_1=0.00)	χ^2=91.7, p=0.00	99.4%
	7	$All\ Trips_2 = -0.226x_0 + 1.0x_1 + 0.077x_2$ (χ_c^2=0. 78, p_c=0.37) (χ_1^2=1573, p_1=0.00) (χ_2^2=0.05 p_2=0.825)	χ^2=91.8, p=0.00	99.4%
		C: intercept; X_1: Number of Employees; X_2: Area Type (neighbourhood income le		
Workplace: Shop	8	$All\ Trips_1 = 0.64 + 0.291x_1 + 0.15x_2$ (χ_C^2=12.82, p_C=0.7) (χ_1^2=10.813, p_1=0.01) (χ_2^2=122.4, p_2=0.00)	χ^2=99.3, p=0.00	83.1%
	9	$All\ Trips_2 = 0.76 + 0.3x_1 + 0.15x_2 - 0.177x_4$ (χ_C^2=13.83, p_C=0.01) (χ^2=10.85, p_1=0.001) (χ_2^2=121.5, p_2=0.00) (χ_4^2=1.99, p_4=0.158)	χ^2=88,44, p=0.00	84.1%
	10	$All\ Trips_3 = 0.99 + 0.24x_1 + 0.097x_3 - 0.21x_4$ (χ_C^2=24.39, p_C=0.00) (χ_1^2=6.52, p_1=0.012) (χ_3^2=121.6 p_3=0.00) (χ_4^2=0.11, p_4=0.23)	χ^2=88,44, p=0.00	84.1%
		C: intercept; X_1 Number of Customers; X_2: Number of Male Employees; X_3: Number of Employees; X_4: Area Type (neighbourhood income level)		

The dummy variable was found significantly related to each mode of transport produced trips, but not for all daily produced trips irrespective of the transport mode (models 4 and 5); marginally insignificant for model 5, though. The number of residents alone is a valid predictor for household trips (r=71.5%) in model number 4; the significance of the dummy variable in the model far exceeds the acceptable thresholds (α=5%). Model 5 considers dividing the number of residents by their role and function. The variation in the daily trips is explained by the number of residents and students in the universities or schools. It yielded a slightly lower prediction (r=64.2%). All coefficients are statistically different from zero, except what is related to the resident income group (x_5).

The difference in the number of workplace-related trips is marginally different by the neighbourhood's" income (0.077 trips more in the LIA), which is not statistically significant in any developed models. The best predictor variable for the daily trips attracted to the office is the number of employees. Each employee increases the number of attracted trips by one trip; the association between the predicted and the observed reaches up to 99% (Models 6 and 7). The attracted trips to retail shops are explained by the number of customers and employees, mainly male employees. The prediction power is high, with a correlation coefficient exceeding 80%, which is very high. Model 8 considers the customers and male employees as explanatory variables. The prediction power is 83.1%, while the inclusion of the neighborhood income level in model 9 increases the prediction power slightly by one percent. Model 10, which considers all employees in addition to the customers, provides similar prediction power for attracted trips to retail shops.

5 DISCUSSION OF RESULTS AND CONCLUSIONS

The travel behaviour patterns in Amman and the related regional socio-economic conditions were investigated in this study. Four surveys with 681 interviews with households, with employees in the workplace as offices or shops in two neighbourhoods of different income levels (1,175 to 2,330 US$) were performed and analysed. The socio-economic differ, which influence the travel pattern; are the high unemployment rate in the LIA (1.93 compared to 0.79) with large family size (5.71 compared to 3.99), which was reflected in the high number of school students per household, and only a 15% of interviewed households own cars in the LIA; one-sixth that of the HIA. Thus, more household members walk (2.47) and use PT (1.67). In contrast, only 0.9 household members use private cars in their mobility in LIA, which is an opposite pattern to the HIA as private car users (2.03) compared to 0.57 and 0.43 for PT users and pedestrians, respectively. Despite few private car users in the LIA, they still made the same number of trips as in the HIA. The trip rates per person (2.2 and 2.0 for the LIA and HIA) showed no statistically significant difference due to income level but not the household rate (5.14 and 3.7 in the LIA and HIA), reflecting the difference in the family size.

To conclude, the residents of the LIA do more traveling by all modes of transport compared to the residents of HIA, which is a reflection of the larger family size and having more students in the schools or universities, on average trip rate per person is (2.2) and (2.0) for the low and high incomes areas respectively.

On average, the subjects spent, on average, 2.5 h in traveling (153.6 and 155 minutes for the LIA and HIA), which is one-sixth of the active time of a person a day (16 h per day). Less time is consumed when traveling by car in the HIA than in LIA (23.1 and 31.5 min per trip), indicating low congestion levels attributed to a better infrastructure network.

The travel time of PT trips is almost alike for the two areas (25.8 and 26.1 min for LIA and HIA, respectively), lower than what was reported at a city level of a 35-minute trip. The same applies to some extent for household walking trips which composes 46.8% of the LIA and only 8.1% of the HIA, consuming 23.7 and 19.9 minutes per trip for LIA and HIA, respectively. Walking as a mobility option accounts for 29% of all trips in the study area, slightly higher than the reported share in a large-scale study (TMMP) in the city that showed 25% of all city trips are completed by walking [25].

To conclude, people in the study area spend 2.5 h in traveling, accounting for one-sixth of a person's active number; PT trips take the longest time while traveling in a personal car consumes the least time compared to other modes, and its takes longer time in LIA. Walking trips share 29% of all trips conducted in the study area.

There is a significant difference in the trip timing as the peak of household trips is in the evening and the morning for the LIA and HIA, respectively. Shop and office-related trips in both areas have two peaks, one in the morning and the other in the evening. A high proportion of morning trips end in the LIA are working trips using personal vehicles, while few trips end in the HIA for education and shopping are made by private car or walking. The morning peak in both areas was at seven when the residents left their homes to work and ended around 14:00-15:00 when they returned home.

To conclude, the demand traveling peaks differ by the type of generated trips (production-household, attraction-workplace) and it peaks at 7:00 at 14:00.

Education is the primary purpose of household members travelling, followed by work. In both areas, a high proportion of morning walking trips is either for work or education. Fewer trips in the afternoon in the LIA made by private car are shopping or socializing trips. There was evidence that travel pattern differs by trip purpose, as detected by the responses in the different surveys. The workplace surveys showed insignificant differences between vehicle ownership levels indicating a higher income level in this group than in the general study. The HIA attracts working trips as 54.4% of trips ended are for work, while LIA mainly produced trips as only 21.1% of the trips completed there are for work. In both areas, shops related trips are conducted by private car, followed by walking in LIA and PT in the HIA. More than two-thirds of trips to work in the offices are undertaken by private cars (73.5% and 70.2% for LIA and HIA, respectively), and less than 10% are made by walking. The mode of PT in use differs by the trip purpose and income level; the white taxi is the most common PT mode for household mobility in the LIA and shop-related trips, but it is not the preferred option for shop or office-related trips in the HIA. The share of the buses as mode PT for working trips is 50% and 57% for LIA and HIA, respectively. Taxi is the common mode PT service in use in the HIA with a share of 50%, 58% and 43% for household, shop and office-related trips, respectively.

To conclude, people mainly travel for education, followed by work, and at least for socializing. The HIA neighbourhoods attracts more working trips than LIA, and most of these trips are conducted by personal cars, which is the more common mode for shopping; public transport is the next common mode of transport for work trips, and the use of yellow taxis and white taxis are the common PT in LIA and HIA, respectively.

Generally, walking distance in HIA is longer than that in the LIA; household walking trip distance, although fewer in number, in the HIA (1,023 m) is longer than in the LIA (290 m). Shoppers either walk or travel by car, then walk to their shopping place with an average distance of 323 meters (5.4 minutes) and 96 meters (1.6 minutes) for LIA and HIA, respectively. The distance from the parking spot to the office is shorter than the shopping trips to and from parking. The LIA's shop owners and employees tend to park on-street, next to their shops, while their peers in the HIA use off-street parking instead. Less than one-third of the subjects of shops and office surveys in the LIA confirmed the availability of off-street parking, which explains why most of them do on-street parking.

To conclude, walking as an independent trip is longer in the HIA. At the same time, it is shorter if it is part of travel that was initially made by personal car, mainly if it is related to shopping where the walking distance from parking spots is shorter than that for offices.

The LIA, on average, produced fewer trips conducted by private car than HIA and more trips made either by PT or walking. The low car ownership level, large household size, and the high number of school students can explain why the GLM models showed such a trend. Household-produced trips can be predicted by household size with a model prediction power of 71%, confirmed in literature [19, 27]. More students, particularly in LIA, walk to school; their number is valid for predicting household walking trips (r=73.6%). Since both the employee and university or college students travel long-distance and could not complete their trips by walking, they were good predictors for private cars and PT trips, respectively. The constructed models did not show a difference in how the area income can explain the number of attracted trips to the workplace. The customers and employees, particularly males, are strong predictors for retail shop trips (r=84%). Male employees compose the vast majority of the study area's workforce, as female presence is less than 31%, which may explain the strong association between the number of trips. A positive correlation was observed between the predicted office-related trips and the employees. The small data set for office trips made it impossible to split the analysis by mode of transport.

To conclude, the daily trip produced by a household can be predicted either by the family size or by variables that stand for the breakdown of the family size by role and function. The number of employees is a valid predictor for office trips. The customers and employee numbers can produce reasonable predictions of retail shop trips. The general trend in the analysis showed that trips in LIA are higher than in HIA, except for shopping trips.

Future Work

The study strived to be inclusive as possible. Still, there were some limitations related to the commercial activities than can be covered in the analysis due to the nature of the study area, where no malls or large shopping centres exist, and the fund availability that limited the size of the study area. Educational facilities as a trip attraction were not included either. Future work could investigate other attraction facilities (shopping centres, schools, universities, health facilities, etc.). The study area can be expanded to include other neighbourhoods with different socio-economic conditions. Data on other variables may be collected and integrated into the transport-mode-based model for daily household trips to improve their prediction power.

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