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# Impacts of built environment and socioeconomic factors on trip-chaining in Abu Dhabi

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A R T I C L E I N F O

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A B S T R A C T

Abu Dhabi, the capital city and the largest Emirate in the United Arab Emirates, aspires to be one of the global cities. A good global city features effective Transportation Demand Management (TDM). This study uses the last survey conducted by the Department of Municipalities and Transportation in 2015 to investigate trip-chaining behaviour in the region. As one of the first studies in the region, this study examines the propensity to make multiple stops with a particular focus on gender, employment status, licensing and mode of travel. The outcomes of the study provide recommendations such as enhancing the public transit system, inclusive planning, addressing work-time pressure, etc., to address trip chaining behaviour and have effective traffic management, and creating a safe environment for all road users of Abu Dhabi, etc. The implication of this study can be used by emerging global cities, especially in the Middle Eastern region for effective TDM.

## Introduction

The definition of trip chaining has been widely discussed and has evolved over time. Existing definitions can generally be classified into two categories (Primerano et al., 2007). The first defines trip chaining as a series of trips that originate and end at home (Grue et al., 2020; Lee et al., 2007; Pang and Zhang, 2019). The second conceptualizes it as a sequence of trips between anchor locations, such as home, work, or school (Concas and DeSalvo, 2014). More recent studies have introduced greater specificity into this definition. The National Household Travel Survey (NHTS) typically identifies anchor locations as home, workplace, or any location where an individual stays for more than 30 min (Wang, 2015; Zhu and Guo, 2022). Drawing on the NHTS definition of anchor points, a *tour* is defined as a journey between two anchored locations—namely, a residential location, a workplace, or another location involving a stay exceeding 30 min. A *chained tour* refers to a tour that includes at least one intermediate stop of fewer than 30 min between anchored locations. This definition aligns with the trip-chaining framework adopted in NHTS documentation (McGuckin et al., 2005; NHTS, 2001) and applied in empirical studies utilizing NHTS datasets (Ahmed et al., 2025; Ahmed and Hyland, 2023; Zhu and Guo, 2022). Tours are composed of individual trips, defined as movements between any two locations. A chained tour consists of multiple shorter trips linked together, whereas a simple tour without intermediate stops constitutes a single trip. Fig. 1 illustrates this conceptualization.

Trip-chaining behavior occurs when individuals combine multiple destinations within a single tour. Examining this behavior enhances understanding of travel decisions and destination choices, thereby supporting the development of appropriate frameworks for transportation policy analysis and implementation (Strathman and Dueker, 1995). For example, chained tours may be both flexible and efficient for individuals with access to private automobiles, increasing reliance on cars and contributing to higher Vehicle Miles Traveled (VMT) (Bautista-Hernández, 2020). Complex chained tours are also associated with a lower likelihood of public transportation use (Hensher and Reyes, 2000; Huang et al., 2021). Additionally, commuting trips may incorporate non-work-related activities during peak hours, thereby increasing peak-hour demand (e.g., parking) in non-work areas and necessitating improved land use–transportation integration. Understanding trip-chaining behavior can enhance urban transportation systems by: (1) accommodating user needs and preferences; (2) optimizing transportation infrastructure; (3) reducing congestion while improving traffic flow; and (4) promoting effective land-use strategies that minimize the need for extensive travel in urban areas.

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The City of Abu Dhabi, the capital of the United Arab Emirates (UAE), aspires to become a global city with advanced physical and digital infrastructure by 2030 (Abu Dhabi Urban Planning Council, 2007). Morphologically, the capital city is primarily monocentric and situated on an island, featuring a gridded street network that facilitates accessibility across multiple travel modes (Taileb et al., 2008). The transportation system is characterized by three dominant modes: private automobiles (including taxis), a public bus network, and active modes such as walking and cycling. Although transportation demand management (TDM) studies in Abu Dhabi have examined public transportation accessibility (Pimenta et al., 2021; Maghelal et al., 2022), road safety (Alkhoori and Maghelal, 2021; Maghelal et al., 2023a), and social capital and health outcomes (Al-Ali et al., 2020), trip-chaining behavior among residents has not been systematically investigated. Moreover, Abu Dhabi's land-use structure differs from that of many global cities. The urban core is characterized by superblocks with dense mixed-use development, while suburban areas consist of large-plot villas with relatively sparse development, predominantly housing the local Emirati population (Alawadi and Benkraouda, 2018). Given that expatriates constitute over 85% of the population in the Emirate of Abu Dhabi, understanding trip-chaining behavior has implications not only for Abu Dhabi but also for other Middle Eastern cities seeking to enhance land use–transportation integration and TDM strategies. Despite these distinctive development and socio-demographic characteristics, the relationship between such contextual factors and trip-chaining behavior remains underexplored. In particular, the nonlinear and interactive effects of gender, employment status, licensing status, and commuting mode have received limited attention. This study is among the first to examine trip-chaining behavior among residents of Abu Dhabi and to assess the influence of socio-demographic, household, and built-environment characteristics on complex chained tours (Fig. 1). Specifically, it evaluates how gender, employment status, licensing status, and commuting mode interact with other determinants of trip-chaining behavior in Abu Dhabi.

Individual and household characteristics have consistently been identified as primary determinants of travel and trip-chaining behavior (Zhu and Guo, 2022; Cheng et al., 2016; Ma et al., 2014). In contrast, the role of the built environment has received comparatively less attention. Furthermore, most existing research has focused on Western and East Asian contexts, while trip-chaining behavior in the Middle East remains largely unexplored.

This gap is particularly significant, as daily life and community practices in many Middle Eastern societies are shaped by Islamic cultural norms emphasizing privacy, accessibility, seclusion, and gender-based spatial considerations (Alawadi et al., 2024). Additionally, the region's hot, arid desert climate presents unique conditions that influence travel behavior. To the best of our knowledge, this study is among the first to integrate individual, household, and built-environment characteristics to analyze trip-chaining behavior within the Middle Eastern context of the UAE.

## Literature review

### *Factors influencing trip-chaining behavior: socio-demographic characteristics*

Previous research has examined demographic and socioeconomic factors such as household composition (Bricka, 2008) and the presence of children (McGuckin et al., 2005) in relation to trip-chaining behavior. For example, Wang (2015) found that the presence of children in a household significantly increases the likelihood of additional stops within a commute tour, reflecting childcare-related responsibilities. Gender and age are also recognized as strong determinants of travel behavior, and their implications for trip chaining have been widely studied (McGuckin and Murakami, 1999; McGuckin et al., 2005; Bhat and Zhao, 2002). Gender-based differences in trip-chaining behavior have been extensively documented. Several studies report that female commuters are more likely than male commuters to generate tours with intermediate stops, as women often assume responsibilities such as dropping off and picking up children, grocery shopping, and participating in social and recreational activities (Ma et al., 2014; McGuckin et al., 2005; Primerano et al., 2007; Wang, 2015). Furthermore, Wang et al. (2011) observed that built-environment characteristics exert a stronger influence on the activity–travel behavior of male household heads compared to female household heads. Other socioeconomic determinants, including income, education, and employment status, have shown mixed effects on trip-chaining behavior. Income is often considered a critical factor in modeling trip-chaining decisions, as it influences sensitivity to travel costs. Some empirical studies suggest that higher income levels are associated with a lower probability of trip chaining (Cheng et al., 2016; Wallace et al., 2000), indicating that higher-income individuals may be less inclined to combine trips due to lower cost sensitivity. Conversely, other studies report that income has an insignificant impact on commuter trip-chaining behavior (Wang, 2015). Similarly, employment status has yielded inconsistent findings. While some studies identify work status as a significant predictor (McGuckin and Murakami, 1999; Strathman et al., 1994), others report substantial differences in chained trips between workers and non-workers (Bianco and Lawson, 1996), as well as faster growth in non-commuting trips relative to commuting trips among both groups (Gordon et al., 1988). Car ownership also plays a significant role, as households without access to a vehicle tend to undertake less complex trip chains compared to those with automobile access (Primerano et al., 2007).

### *Factors influencing trip-chaining behaviour: built environment*

The built environment has been widely examined in studies seeking to understand travel behaviour. The study by Cervero and Kockelman (1997) introduced the "3Ds" framework—density, diversity, and design—to conceptualize key built-environment attributes influencing travel demand. This framework was later expanded to the "5Ds" with the

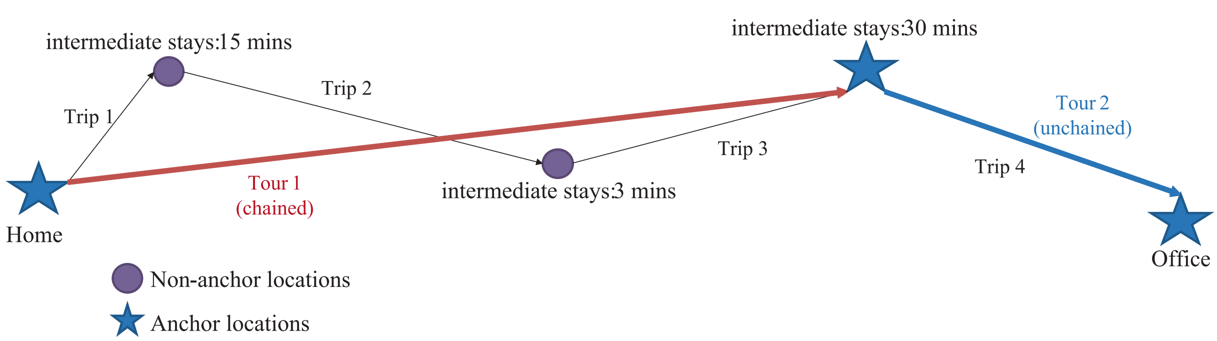


**Fig. 1.** Definition of related concepts.

inclusion of destination accessibility and distance to transit (Ewing and Cervero, 2001). Subsequently, the “7Ds” framework incorporated demand management and demographics and is currently among the most comprehensive and widely applied conceptualizations (Ewing and Cervero, 2010).

Although the progression from 3Ds to 7Ds provides increasingly nuanced categorizations of built-environment attributes, the expanded frameworks are data-intensive and require detailed spatial disaggregation. In data-restrictive contexts such as Abu Dhabi, obtaining disaggregated built-environment measures is challenging and often constrained by privacy regulations. Consequently, several recent studies conducted in data-limited environments have adopted more parsimonious built-environment measures. For instance, Tiwari et al. (2023) employed the 3Ds framework to assess the alignment of urban form with Transit-Oriented Development (TOD) principles across two districts in Naples, Italy. Researchers frequently adapt built-environment variables to suit context-specific conditions, sometimes excluding less relevant indicators or incorporating additional variables. Liu et al. (2020), in their review of 29 TOD studies, noted that most empirical research relies on either the 3D or 5Ds framework. Similarly, Hu et al. (2021) utilized the 5Ds framework to examine factors influencing electric vehicle use intensity but omitted distance to transit due to limited relevance and incorporated charging pile density as a context-specific variable. Considering contextual constraints and data limitations, the present study adopts the 3Ds framework to assess built-environment characteristics.

Density encompasses measures such as population density and employment density. Higher-density areas are generally associated with greater trip generation (Hanson, 1982). However, lower-density residential areas have been shown to reduce the likelihood of linking multiple trips by car (Greenwald and McNally, 2008). Population density, a central component of the density dimension, has yielded mixed findings. Grue et al. (2020) reported that higher population density is associated with simpler trip chains. Similarly, Wang (2015) found that doubling urban population density resulted in a statistically significant but modest 3.3% reduction in commute stops, suggesting that higher density may be associated with fewer chained trips. In contrast, Adler and Ben-Akiva (1979) found that higher employment density is positively associated with trip chaining, indicating that employment concentration may increase opportunities for linking multiple activities within a single tour.

The diversity dimension refers to the mix and distribution of land uses within an area, typically measured using land-use mix indices (Maghelal and Capp, 2011). It captures variations in residential, commercial, office, industrial, institutional, and recreational land uses per developed acre. Pang and Zhang (2019) demonstrated that greater land-use mix is associated with reduced vehicular travel distances. Similarly, Chowdhury and Scott (2020) found that neighbourhood-level land-use diversity—including residential, commercial, and recreational uses—encourages trip chaining and significantly influences travel behaviour. Harding et al. (2015) further noted that destinations characterized by high density, diverse land uses, and transit accessibility facilitate efficient trip chaining. In addition, Hanson (1982) observed that proximity to shopping opportunities within residential neighbourhoods reduces the length of chained trips. Krizek (2003) found that improved accessibility to destinations increases the likelihood of engaging in trip chaining. Collectively, these findings suggest that land-use diversity and accessibility play important roles in shaping the complexity and efficiency of travel patterns.

The design dimension encompasses street network characteristics such as intersection density, arterial speed limits, and street widths. Street design influences travel behaviour by shaping connectivity and accessibility. Parking availability at urban destinations has been identified as an important determinant of travel patterns; Grue et al. (2020) found that greater parking availability is associated with simpler travel chains. Walkability and accessibility are also critical factors. Shay and Khattak (2012) demonstrated that areas with higher walkability and accessibility are associated with lower vehicle ownership and increased trip generation.

Concas and DeSalvo (2014) reported that household proximity to transit influences the likelihood of engaging in trip chaining, particularly among individuals residing farther from transit hubs. Furthermore, Noland and Thomas (2007) argued that areas characterized by lower building density per unit of land are associated with greater reliance on trip chaining and more complex travel patterns.

Overall, the influence of built-environment determinants on travel behaviour varies across contexts. In Middle Eastern settings, while travel behaviour has often been examined using individual and household characteristics, the role of the built environment remains comparatively underexplored.

### *Travel studies in the context of Abu Dhabi*

Existing research on travel behaviour in Abu Dhabi has produced diverse findings. One major area of investigation concerns mode choice. Alkaabi (2014) found that employment type, education level, nationality, and distance to public transit stations significantly influence the likelihood of choosing public transportation as a primary mode.

Hasan et al. (2023) examined the impact of enhanced public transportation services on congestion in Abu Dhabi using micro-simulation techniques. Their findings indicated that improvements in public transportation services reduced congestion and traffic bottlenecks and significantly increased road capacity. While this study relied on traffic-count data for simulation, most travel behaviour studies in Abu Dhabi have employed individual-level survey methodologies (Hamad et al., 2024; Alkaabi, 2023; Maghelal et al., 2023b; Abulibdeh, 2022; Almardood and Maghelal, 2020). Studies examining active transportation modes have similarly relied on survey data to assess usage patterns, attitudes, and perceptions (Hamad et al., 2021; Maghelal et al., 2021). For example, Hamad et al. (2021), based on a survey of 2,000 campus travelers, found that gender significantly influences the likelihood of selecting bus services as the primary commuting mode. In another study, Badri et al. (2012) reported that parents consider factors such as crosswalk availability, road conditions, and community safety when determining whether their children can safely walk or cycle to school.

Despite these contributions, understanding of travel behaviour in Abu Dhabi remains limited, particularly with respect to trip-chaining behaviour and its determinants. To date, no study has comprehensively examined trip chaining using official travel survey data collected by the Abu Dhabi Department of Municipalities and Transportation (ADMT). This study addresses this gap by investigating the influence of individual, household, and built-environment characteristics on trip-chaining behaviour using recent official travel survey data and applying econometric analysis techniques.

## Methodology

### *Study area*

The Department of Transportation in Abu Dhabi developed the Strategic Transportation Evaluation and Assessment Model (STEAM-1 and STEAM-2), which is based on comprehensive travel surveys conducted within the Emirate of Abu Dhabi. In 2015, the Abu Dhabi Department of Municipalities and Transportation (ADMT) spearheaded a detailed travel survey covering major regions of the Emirate, including Abu Dhabi City, Al Ain, and Al Gharbia. The survey dataset is organized into three primary components. The first section contains household-level information, including residential addresses. To ensure confidentiality, precise addresses were aggregated into Traffic Analysis Zones (TAZs). The second section captures socio-demographic characteristics of respondents, including age, gender, employment status, primary commuting mode, and occupation type. The third component comprises


**Fig. 2.** Number of trips generated from each TAZ in Abu Dhabi.

**Table 1**
Summary statistics.

| | mean | sd | min | max |
|---|---|---|---|---|
| **Dependent Variable:** | | | | |
| Total number of intermediate stops | 0.34 | 0.85 | 0.00 | 9.00 |
| **Independent Variable:** | | | | |
| *Demographic characteristics* | | | | |
| Female (ref: Male) | 0.37 | 0.48 | 0.00 | 1.00 |
| Age | | | | |
| Age between 16 and 18 | 0.06 | 0.24 | 0.00 | 1.00 |
| Age between 19 and 25 | 0.13 | 0.34 | 0.00 | 1.00 |
| Age between 26 and 59 | 0.77 | 0.42 | 0.00 | 1.00 |
| Age above 60 | 0.03 | 0.17 | 0.00 | 1.00 |
| Income level | | | | |
| Less than 1000 AED (including no income) | 0.01 | 0.11 | 0.00 | 1.00 |
| > 1000 AED - 12,000 AED | 0.31 | 0.46 | 0.00 | 1.00 |
| > 12,000 AED – 50,000 AED | 0.53 | 0.50 | 0.00 | 1.00 |
| > 50,000 AED – 100,000 AED | 0.12 | 0.33 | 0.00 | 1.00 |
| > 100,000 AED | 0.02 | 0.15 | 0.00 | 1.00 |
| Driver's license (ref: No driver's license) | 0.63 | 0.48 | 0.00 | 1.00 |
| Employed (ref: Unemployed/ Student) | 0.71 | 0.45 | 0.00 | 1.00 |
| Average travel distance per trip (m) | 21229.68 | 33725.61 | 0.00 | 371760.31 |
| Usual travel mode | | | | |
| car | 0.56 | 0.50 | 0.00 | 1.00 |
| bus | 0.16 | 0.37 | 0.00 | 1.00 |
| others | 0.28 | 0.45 | 0.00 | 1.00 |
| *Household attributes* | | | | |
| Total children in Dwelling | 1.53 | 1.64 | 0.00 | 20.00 |
| Total adults in Dwelling | 2.99 | 2.06 | 1.00 | 40.00 |
| *Built environments* | | | | |
| Population density(persons sq km) | 5532.60 | 8292.70 | 0.00 | 27211.97 |
| Average Number of Fourway Intersections | 0.49 | 0.27 | 0.00 | 0.97 |
| Average Road Speed (kph) | 49.77 | 9.38 | 26.00 | 98.00 |
| Road Density (length/area) | 0.04 | 0.03 | 0.00 | 0.28 |
| Public transport station number | 3.11 | 8.65 | 0.00 | 77.00 |
| Land use diversity | 0.45 | 0.19 | 0.00 | 0.99 |
| Parking lot number | 1.08 | 3.07 | 0.00 | 27.00 |

a one-day travel diary in which respondents recorded all travel activities undertaken on a designated working day. Although participants initially provided detailed origin and destination addresses, these were subsequently aggregated to TAZs to preserve privacy. The diary records trip purpose, transportation mode, solo driving instances, parking information, and departure and arrival times. Fig. 2 illustrates the spatial distribution of trips generated across TAZs.

In addition to the survey data, this study incorporates built-environment measures, including residential density, road density, land-use mix, transit availability, and parking supply. Residential density data were spatially integrated with census boundaries and TAZs. Furthermore, vehicle miles traveled (VMT) were estimated using the Google Distance Matrix API and the Open-Source Routing Machine (OSRM) API, accounting for the reported travel mode. Parking data were extracted from OpenStreetMap using Python.

Observations with missing key attributes—such as gender, income, or age—were excluded from the analysis. After data cleaning, additional aggregation was performed to accommodate different modeling specifications.

The original dataset included 24,198 individuals. Since this study focuses on travel behavior, 7,960 individuals who reported no travel on the survey day were excluded. Given that children's travel behavior is largely dependent on parental decisions, individuals younger than 15 years of age (4,506 observations) were also excluded. Additionally, 2,679 observations with missing values for independent variables (e.g., income, employment status) were removed. After excluding non-travelers, minors, and incomplete records, the final analytical sample consists of 9,052 individual travelers.

## Empirical specification

The empirical specification for individual-level analysis is summarized as follows:

$$Y = f(\text{individual characteristics}, \text{household characteristics}, \text{built environment})$$

The dependent variable is the total number of intermediate stops made by an individual during the travel day. This variable is constructed from the travel diary, in which respondents documented departure times, arrival times, and duration of stay at each destination.

Fig. 1 presents a hypothetical travel trajectory illustrating the operational definition of a tour. A tour is defined as a journey between two anchored locations. In the example, a traveler departs from home and ultimately arrives at the workplace, completing two tours. During the first tour, the traveler makes two intermediate stops, whereas the second tour includes no intermediate stops. Accordingly, the total number of stops for this individual is two. A higher value of the dependent variable indicates a greater number of detours and, therefore, more complex trip-chaining behavior within the travel day.

The model includes three sets of independent variables, namely individual level characteristics, household attributes, and residential built environment. Individual characteristics include age, income, employment status, possession of driver's license, most frequently used travel mode and average travel distance per trip on the diary day. Household characteristics are represented by the number of children in the family. Residential built environments are measured by population density, average number of four-way intersections, average road speed, road density, public transportation station number, land use diversity and number of parking lots. Table 1 reports the summary statistics of the variables used in our analysis. Owing to the presence of skewness in our continuous independent variables, this study employed a normalization transformation to address this skewness in the dataset.

*Zero-Inflated regression model*

The dependent variable exhibits a substantial proportion of zero observations, with approximately 82% of individuals reporting no intermediate stops. Such excess zeros render traditional linear regression models inappropriate, as the outcome variable is non-negative and highly skewed. The zeros observed in the dataset are not missing values but reflect meaningful behavioral outcomes—namely, individuals who did not engage in trip chaining on the survey day. Understanding the determinants of these zero outcomes is therefore substantively important. Excess zeros and count outcomes violate the assumptions of linear regression, particularly normality and homoscedasticity.

To address these issues, prior research has employed nonlinear modeling approaches. Amemiya (1984) introduced early regression frameworks for limited dependent variables. Subsequently, zero-inflated models were developed to accommodate count data with excessive zeros (Lambert, 1992). Zero-inflated models assume that the observed outcome arises from two distinct processes: with probability $p$, the only possible outcome is zero (structural zeros), and with probability $1 - p$, the count outcome follows a specified distribution (Lambert, 1992). In the context of trip chaining, individuals may have zero stops either because circumstances make trip chaining highly unlikely (structural zeros) or because they simply did not engage in chaining on that particular day. Common zero-inflated models include the Zero-Inflated Poisson (ZIP), Zero-Inflated Negative Binomial (ZINB), and Zero-Inflated Binomial (ZIB) models (Lambert, 1992; Greene, 1994; Hall, 2000). Travel behavior studies have frequently employed these approaches to model excess zeros. For example, Bautista-Hernández (2020) used a Zero-Inflated Negative Binomial (ZINB) model to examine additional commuter stops in relation to built-environment and sociodemographic characteristics. Their dataset also exhibited a high proportion of zeros, with 73.45% for car tours, 83.41% for transit tours, and 39.59% for mixed-mode tours. In this study, the Zero-Inflated Negative Binomial (ZINB) model is adopted. Compared to the ZIP model, ZINB accommodates over-dispersion in count data. A likelihood-ratio test comparing the ZINB and ZIP models indicates that ZINB provides a superior fit for modeling intermediate stops in this dataset.

*Heterogeneity analysis*

The regression model also assesses the role of the determinants of across gender, drivers, and public transit versus private vehicles users. Specifically, we estimate how the probability to trip chain varies across males and females, those employed versus unemployed and the user of public transit versus private vehicles for their trip mode.

## Results

*Trip-Chaining behavior*

The results of the Zero-Inflated Negative Binomial (ZINB) model estimating trip-chaining behavior are presented in Table 2. Marginal effects are illustrated using forest plots, with detailed estimates provided in Table A1 in the Appendix. Table 2 reports findings for both components of the ZINB model. The first component is a logistic regression that estimates the probability that an individual does not exhibit trip-chaining behavior. The second component is a Negative Binomial regression that predicts the number of intermediate stops among individuals who engage in trip chaining. In the logistic portion of the ZINB model, excessive zeros are treated as “1,” indicating the absence of trip chaining. Consequently, a negative coefficient in the logistic model corresponds to a higher likelihood of engaging in trip chaining. In contrast, in the Negative Binomial component, positive coefficients indicate a positive association between the independent variables and the expected number of intermediate stops.

Thus, negative effects in the logistic model imply a greater probability of trip chaining, while positive effects in the count model indicate a higher number of stops among those who chain trips. When coefficients in both components share the same sign, the independent variable exerts opposing influences on the probability of trip chaining and the intensity (number of stops) of chained trips. Marginal effects were subsequently calculated to assess the overall impact of each determinant on the number of intermediate stops (Fig. 3).

Column 1 of Table 2 presents the effects of individual-level determinants on trip-chaining behavior. The results indicate that females, individuals earning between AED 50,000 and AED 100,000, those reporting longer average trip distances, bus users as their primary travel mode, and individuals with more children exhibit a lower propensity to engage in trip chaining. In addition, built-environment characteristics such as a higher number of four-way intersections, longer average road length, and a greater number of bus stops are associated with a lower probability of engaging in trip chaining. Conversely, individuals aged 16–18 years, those earning between AED 1,000 and AED 12,000, employed individuals, and those using transportation modes other than private cars demonstrate a higher propensity to engage in trip chaining. Built-environment measures such as higher population density and greater average road speed are also positively associated with the likelihood of trip chaining.

The full-sample model (combining both the logistic and Negative Binomial components) reveals that females are less likely to engage in trip chaining and, when they do, they make fewer intermediate stops compared to males. The total marginal effect indicates that females make, on average, 0.23 fewer intermediate stops than males.

Relative to individuals aged 26–59 years (reference group), younger individuals aged 16–18 years are more likely to engage in trip chaining. However, individuals aged 16–18 and 19–25 make fewer stops (0.22 and 0.06 fewer stops, respectively) than those aged 26–59. This pattern likely reflects home-to-school or home-to-university travel with limited intermediate activities.

Higher income levels are significantly associated with trip-chaining propensity but do not significantly influence the number of intermediate stops among those who chain trips. Similarly, employed individuals are more likely to engage in trip chaining; however, employment status does not significantly affect the number of stops once chaining occurs. Possession of a driver’s license exhibits an interesting pattern. While it does not significantly influence the likelihood of engaging in trip chaining, it is positively and significantly associated with the number of intermediate stops. The marginal effects indicate that holding a driver’s license increases the expected number of intermediate stops by approximately 0.22.

Average travel distance is negatively associated with both the propensity to engage in trip chaining and the number of intermediate stops, with a marginal reduction of 0.22 stops. Bus use does not significantly affect the probability of trip chaining but is positively associated with the number of intermediate stops. In contrast, individuals using other modes of transportation (e.g., walking and cycling) are more likely to engage in trip chaining and report a higher number of stops, with a positive marginal effect of 0.29.

The number of children in a household decreases the probability of engaging in trip chaining but increases the number of intermediate stops among those who chain trips. The total marginal effect indicates that a one standard deviation (SD) increase in the number of children is associated with an increase of 0.09 intermediate stops. Similarly, the number of adults in a household does not significantly affect the propensity to engage in trip chaining but increases the number of intermediate stops among individuals who chain trips. A one SD increase in the number of adults corresponds to an increase of approximately 0.02 intermediate stops.

Built-environment variables exhibit nuanced relationships with trip-chaining behavior. Population density increases the likelihood of engaging in trip chaining but decreases the number of intermediate stops among those who chain trips. This finding may reflect the land-use

**Table 2**
ZINB results: Coefficients of Negative Binomial and Logit models.

| | Full sample | Female | Male | Non-Driver | Driver | PT users | PV users |
|---|---|---|---|---|---|---|---|
| **Inflate: Logit** | | | | | | | |
| *Individual characteristics* | | | | | | | |
| Female (ref: Male) | 0.622* | | | 0.259 | 0.292 | 0.022 | 0.145 |
| | (0.298) | | | (0.719) | (0.157) | (0.199) | (0.542) |
| Age (ref: Age between 26 and 59) | | | | | | | |
| Age between 16 and 18 | −2.883** | −1.355 | 0.483 | −4.234** | | 1.194* | −2.095 |
| | (0.889) | (0.916) | (0.552) | (1.534) | | (0.556) | (1.747) |
| Age between 19 and 25 | −0.406 | −0.226 | 0.539** | −1.277 | 0.702*** | 0.592** | −1.165 |
| | (0.417) | (0.433) | (0.206) | (0.820) | (0.209) | (0.206) | (0.919) |
| Age above 60 | −0.073 | −14.113 | −0.285 | 0.751 | −0.401 | 0.065 | −0.921 |
| | (0.632) | (663.656) | (0.261) | (1.270) | (0.281) | (0.316) | (1.354) |
| Income (ref: > 12,000 AED – 50,000 AED) | | | | | | | |
| Less than 1000 AED (including no income) | −1.515 | −4.254 | −0.443 | −1.742 | 0.340 | −0.880 | −0.117 |
| | (1.211) | (3.688) | (0.533) | (1.329) | (0.623) | (0.717) | (1.980) |
| > 1000 AED - 12,000 AED | −1.325** | −0.879 | −0.018 | −1.333 | −0.009 | −0.051 | 0.829* |
| | (0.445) | (0.483) | (0.136) | (0.787) | (0.133) | (0.178) | (0.410) |
| > 50,000 AED – 100,000 AED | 0.789** | 0.229 | 0.383* | −0.567 | 0.329* | 0.151 | −0.463 |
| | (0.274) | (0.281) | (0.186) | (0.760) | (0.155) | (0.212) | (0.835) |
| > 100,000 AED | 0.442 | −0.553 | 1.002** | 3.755 | 0.314 | 0.336 | 1.371 |
| | (0.722) | (0.982) | (0.378) | (3.177) | (0.344) | (0.433) | (1.373) |
| Driver's license (ref: No driver's license) | −0.533 | −0.330 | −0.550** | | | −0.525** | −2.075*** |
| | (0.345) | (0.275) | (0.191) | | | (0.183) | (0.496) |
| Employed (ref: Unemployed/ Student) | −2.079*** | −2.538*** | −0.152 | −5.475*** | 0.086 | −0.105 | −2.595* |
| | (0.461) | (0.701) | (0.222) | (1.314) | (0.232) | (0.241) | (1.142) |
| Average travel distance per trip (m) | 0.737*** | 0.649* | 0.158 | 0.986 | 0.191 | 0.378* | −0.351 |
| | (0.164) | (0.279) | (0.138) | (0.563) | (0.128) | (0.166) | (0.367) |
| Usual travel mode (ref: car) | | | | | | | |
| bus | 1.230** | −0.634 | 0.293 | 0.474 | 0.785** | | |
| | (0.462) | (0.848) | (0.219) | (1.040) | (0.275) | | |
| others | −3.082*** | −3.160*** | −0.480** | −5.821*** | −0.673** | −0.850*** | |
| | (0.483) | (0.690) | (0.178) | (1.668) | (0.210) | (0.222) | |
| *Household attributes:* | | | | | | | |
| Total children in Dwelling | 0.336** | 0.233 | −0.168* | −0.681* | −0.103 | −0.084 | −0.897*** |
| | (0.112) | (0.119) | (0.066) | (0.275) | (0.063) | (0.082) | (0.243) |
| Total adults in Dwelling | 0.107 | 0.526** | −0.154*** | −0.086 | 0.183* | −0.156*** | −0.979 |
| | (0.084) | (0.175) | (0.044) | (0.163) | (0.074) | (0.046) | (0.621) |
| *Built environments:* | | | | | | | |
| Population density (persons sq km) | −5.638*** | −0.236 | −0.190 | −0.041 | −0.127 | −0.037 | −0.040 |
| | (1.667) | (0.177) | (0.105) | (0.483) | (0.091) | (0.131) | (0.166) |
| Average Number of Fourway Intersections | 0.489*** | 0.316* | −0.065 | 0.639* | 0.011 | −0.014 | −0.280 |
| | (0.133) | (0.127) | (0.062) | (0.259) | (0.059) | (0.074) | (0.216) |
| Average Road Speed (kph) | −0.342* | −0.365** | −0.232*** | 0.431 | −0.267*** | −0.190* | −0.295 |
| | (0.158) | (0.139) | (0.062) | (0.273) | (0.061) | (0.078) | (0.159) |
| Average Road Length (m) | 0.400*** | 0.406* | 0.131* | 0.232 | 0.202** | 0.190* | −0.620 |
| | (0.097) | (0.161) | (0.053) | (0.201) | (0.064) | (0.078) | (0.552) |
| Public transport station number | 0.386*** | 0.020 | 0.086 | 0.379** | 0.060 | 0.089 | −0.171 |
| | (0.090) | (0.430) | (0.056) | (0.147) | (0.074) | (0.060) | (0.302) |

(continued on next page)

**Table 2** (*continued*)

| | Full sample | Female | Male | Non-Driver | Driver | PT users | PV users |
|---|---|---|---|---|---|---|---|
| Land use diversity | 0.058 | −0.195 | 0.056 | 0.334 | −0.000 | −0.072 | 0.321 |
| | (0.130) | (0.111) | (0.058) | (0.259) | (0.054) | (0.069) | (0.174) |
| Parking lot number | 0.100 | 0.001 | −0.216 | −4.359* | −0.142 | −0.187 | −0.975** |
| | (0.134) | (0.081) | (0.133) | (2.158) | (0.081) | (0.122) | (0.342) |
| Constant | −1.695 | 3.469*** | 0.880** | 3.907** | 0.280 | 1.381*** | 2.045 |
| | (1.296) | (0.732) | (0.332) | (1.470) | (0.257) | (0.330) | (1.397) |
| **Count: Negative Binomial** | | | | | | | |
| *Individual characteristics* | | | | | | | |
| Female (ref: Male) | −0.592*** | | | −0.934*** | −0.366*** | −0.638*** | −0.643*** |
| | (0.079) | | | (0.201) | (0.103) | (0.125) | (0.139) |
| Age (ref: Age between 26 and 59) | | | | | | | |
| Age between 16 and 18 | −1.199*** | −0.938 | −0.651 | −1.406*** | | −0.494 | −0.422 |
| | (0.243) | (0.508) | (0.434) | (0.359) | | (0.505) | (0.573) |
| Age between 19 and 25 | −0.236* | −0.022 | −0.015 | −0.210 | 0.065 | 0.125 | −0.216 |
| | (0.104) | (0.214) | (0.145) | (0.169) | (0.155) | (0.148) | (0.203) |
| Age above 60 | 0.242 | −1.172** | 0.232 | 0.142 | 0.133 | −0.074 | 0.476* |
| | (0.137) | (0.387) | (0.141) | (0.440) | (0.142) | (0.178) | (0.216) |
| Income (ref: > 12,000 AED – 50,000 AED) | | | | | | | |
| Less than 1000 AED (including no income) | −0.255 | −2.075* | −0.084 | −0.380 | 0.135 | −0.571 | 0.077 |
| | (0.264) | (0.836) | (0.318) | (0.425) | (0.394) | (0.365) | (0.611) |
| > 1000 AED - 12,000 AED | −0.113 | −0.688*** | 0.105 | −0.354* | 0.043 | −0.084 | 0.301** |
| | (0.068) | (0.173) | (0.084) | (0.177) | (0.079) | (0.109) | (0.108) |
| > 50,000 AED – 100,000 AED | 0.194 | 0.317 | 0.068 | 0.064 | 0.137 | 0.166 | −0.157 |
| | (0.103) | (0.170) | (0.121) | (0.320) | (0.101) | (0.124) | (0.134) |
| > 100,000 AED | −0.277 | −0.381 | 0.249 | −0.672 | 0.096 | 0.232 | −0.177 |
| | (0.237) | (0.458) | (0.265) | (1.282) | (0.227) | (0.252) | (0.349) |
| Driver's license (ref: No driver's license) | 0.567*** | 0.702*** | 0.162 | | | 0.520*** | −0.442 |
| | (0.081) | (0.136) | (0.126) | | | (0.115) | (0.230) |
| Employed (ref: Unemployed/ Student) | −0.109 | −0.780*** | 0.066 | −0.477* | 0.080 | −0.113 | 0.467 |
| | (0.102) | (0.174) | (0.135) | (0.196) | (0.135) | (0.147) | (0.382) |
| Average travel distance per trip (m) | −0.572*** | −0.260 | −0.657*** | −0.743*** | −0.544*** | −0.489*** | −0.749*** |
| | (0.066) | (0.180) | (0.097) | (0.220) | (0.092) | (0.125) | (0.077) |
| Usual travel mode (ref: car) | | | | | | | |
| bus | −0.028 | −0.865 | −0.008 | −0.444 | 0.258 | | |
| | (0.124) | (0.464) | (0.154) | (0.332) | (0.206) | | |
| others | 0.432*** | −0.267 | 0.382*** | −0.259 | 0.450*** | 0.294 | |
| | (0.089) | (0.205) | (0.106) | (0.287) | (0.113) | (0.154) | |
| *Household attributes:* | | | | | | | |
| Total children in Dwelling | 0.294*** | 0.360*** | 0.146*** | 0.069 | 0.183*** | 0.130* | 0.117* |
| | (0.033) | (0.068) | (0.038) | (0.074) | (0.040) | (0.051) | (0.047) |
| Total adults in Dwelling | 0.076** | 0.098 | 0.007 | 0.113*** | 0.020 | 0.033 | −0.275*** |
| | (0.024) | (0.100) | (0.020) | (0.034) | (0.047) | (0.019) | (0.069) |
| *Built environments:* | | | | | | | |
| Population density (persons sq km) | −0.171*** | −0.111 | −0.218*** | −0.183* | −0.144** | −0.162* | −0.068 |
| | (0.031) | (0.062) | (0.054) | (0.084) | (0.048) | (0.077) | (0.050) |
| Average Number of Fourway Intersections | 0.046 | 0.116* | −0.029 | 0.118 | −0.001 | −0.047 | −0.032 |
| | (0.030) | (0.056) | (0.038) | (0.072) | (0.035) | (0.044) | (0.048) |
| Average Road Speed (kph) | 0.092** | −0.071 | 0.025 | 0.179* | −0.009 | −0.052 | 0.112** |
| | (0.029) | (0.065) | (0.035) | (0.073) | (0.033) | (0.044) | (0.042) |
| Average Road Length (m) | 0.182*** | 0.043 | 0.098* | 0.139 | 0.077 | 0.230*** | −0.143** |

(*continued on next page*)

**Table 2** (*continued*)

| | Full sample | Female | Male | Non-Driver | Driver | PT users | PV users |
|---|---|---|---|---|---|---|---|
| | (0.047) | (0.112) | (0.045) | (0.084) | (0.049) | (0.054) | (0.053) |
| Public transport station number | 0.111* | −0.201 | 0.006 | 0.131 | 0.024 | 0.093* | −0.255* |
| | (0.054) | (0.238) | (0.046) | (0.133) | (0.046) | (0.046) | (0.103) |
| Land use diversity | 0.038 | 0.019 | 0.080* | 0.083 | 0.069* | 0.022 | 0.111** |
| | (0.028) | (0.055) | (0.036) | (0.072) | (0.033) | (0.041) | (0.042) |
| Parking lot number | 0.048 | 0.010 | −0.025 | −0.098 | −0.014 | −0.085 | 0.024 |
| | (0.031) | (0.050) | (0.044) | (0.062) | (0.038) | (0.050) | (0.033) |
| Constant | −1.167*** | −0.481 | −0.458* | −0.181 | −0.234 | −0.272 | −1.021 |
| | (0.166) | (0.322) | (0.215) | (0.371) | (0.154) | (0.228) | (0.532) |
| **lnalpha** | 0.459*** | −1.614* | −1.366*** | 0.738*** | −1.852*** | −2.117*** | 0.338* |
| | (0.078) | (0.683) | (0.302) | (0.147) | (0.387) | (0.629) | (0.165) |
| **Observations** | 9052.000 | 3317.000 | 5735.000 | 3387.000 | 5665.000 | 3950.000 | 5102.000 |
| **AIC** | 1.35 | 1.05 | 1.52 | 0.9500000000000001 | 1.58 | 1.34 | 1.36 |
| **BIC** | −69891.29000000001 | −23071.7 | −40587.68 | −23989.54 | −39642.56 | −27103.93 | −36317.16 |
| **Log Likelihood** | −6048.13 | −1694.47 | −4293.15 | −1554.11 | −4436.99 | −2592.76 | −3411.13 |
| **McFadden's Adj R2** | 0.07 | 0.09 | 0.06 | 0.07 | 0.05 | 0.09 | 0.05 |

Standard errors in parentheses; *p < 0.05, **p < 0.01, ***p < 0.001.

characteristics of dense TAZs in Abu Dhabi, where mixed-use development and proximity to major destinations (e.g., shopping malls) enable individuals to complete multiple activities within fewer stops. However, the marginal effects indicate that a one SD increase in population density increases the average number of intermediate stops by 0.19, albeit modestly. This apparent inconsistency suggests complex interactions between trip-chaining propensity and activity concentration in dense urban areas and warrants further investigation.

The average number of four-way intersections and average road length reduce the probability of engaging in trip chaining, whereas higher average road speed increases this probability. Among individuals who engage in trip chaining, higher average road speed and longer road length are associated with an increase in the number of intermediate stops. A one SD increase in either average road speed or road length increases intermediate stops by approximately 0.05.

Overall, built-environment features that facilitate automobile use—such as higher speed limits and extended road networks—appear to encourage more intermediate stops. In contrast, a greater number of public transport stations reduces the propensity to engage in trip chaining, although it slightly increases the number of stops among those who chain trips.

*Heterogeneity analysis: gender*

This section examines whether the determinants of trip-chaining behavior differ by gender. Columns 2 and 3 of Tables 2 and 3 present the gender-based heterogeneity results. The discussion primarily focuses on marginal effects that differ between male and female travelers, as summarized in Fig. 4 and Table A1, while highlighting noteworthy patterns from the regression results in Table 2 where relevant.

Consistent with the full-sample analysis, female travelers exhibit fewer intermediate stops on average compared to male travelers. This pattern may reflect gender-based differences in travel demand and trip purpose, shaped by disparities in social roles, workplace expectations, and household responsibilities. These systematic gender differences may also moderate the influence of other determinants on trip-chaining behavior.

Age and income demonstrate gender-specific effects. Age is statistically significant only among males. Compared to male travelers aged 26–59 years, males aged 16–18 make 0.30 fewer intermediate stops, those aged 19–25 make 0.10 fewer stops, and those aged above 60 make 0.20 more stops. Younger males, particularly those aged 16–18, are likely to be students or in the early stages of their careers, with relatively limited discretionary responsibilities. Their travel patterns are therefore more direct, primarily oriented toward school, work, or home. In contrast, older males may have more flexible schedules due to retirement or reduced work commitments, enabling them to engage in additional intermediate stops for social visits, errands, or leisure activities. In contrast, age does not significantly influence trip chaining among females. This lack of variation may reflect relatively stable and structured daily routines among women in the region, particularly those associated with household responsibilities and caregiving roles, which may not vary substantially across age groups.

Income effects are statistically significant and consistent only among female travelers. Relative to females earning AED 12,000–50,000, those earning less than AED 1,000 make 0.20 fewer intermediate stops, and those earning AED 1000–12,000 make 0.10 fewer stops. Lower-income females may have limited access to resources, such as private vehicles and discretionary income, constraining their ability to engage in additional non-essential stops. They may also work in lower-paying occupations with less schedule flexibility, further limiting opportunities for intermediate activities.

Although marginal effects of employment status are not statistically significant for either gender (Fig. 4), the regression results in Table 2 reveal distinct patterns. Among females, employment status is positively associated with the probability of trip chaining but negatively associated with the number of intermediate stops conditional on chaining. In other words, employed women are more likely to engage in chained trips, but they make fewer stops compared to unemployed women. No statistically significant differences are observed between employed and unemployed males in either trip-chaining propensity or complexity.

With respect to primary travel mode, female public transport (PT) users make 0.04 fewer intermediate stops on average compared to female private vehicle (PV) users. Given the relatively limited spatial coverage of the public transport network in Abu Dhabi, conducting extensive trip chains via transit may be time-consuming and less convenient. Additionally, safety considerations and household responsibilities may discourage additional detours for women relying primarily on public transportation. Regarding household composition, the number of children is positively associated with the number of stops for both males and females. However, the number of adults in the household increases intermediate stops only for males. This suggests that responsibilities associated with children may be shared across genders, whereas care or support for other adults (e.g., elderly family members) may be more frequently undertaken by males, potentially reflecting cultural norms regarding household roles.

Built-environment effects also differ by gender. Population density exerts a negative effect on male trip-chaining intensity: a one standard deviation (SD) increase in population density reduces the average number of stops by 0.05 for males. In contrast, male travelers exhibit more intermediate stops in response to increases in average road speed and parking availability, while female travelers show increased stops

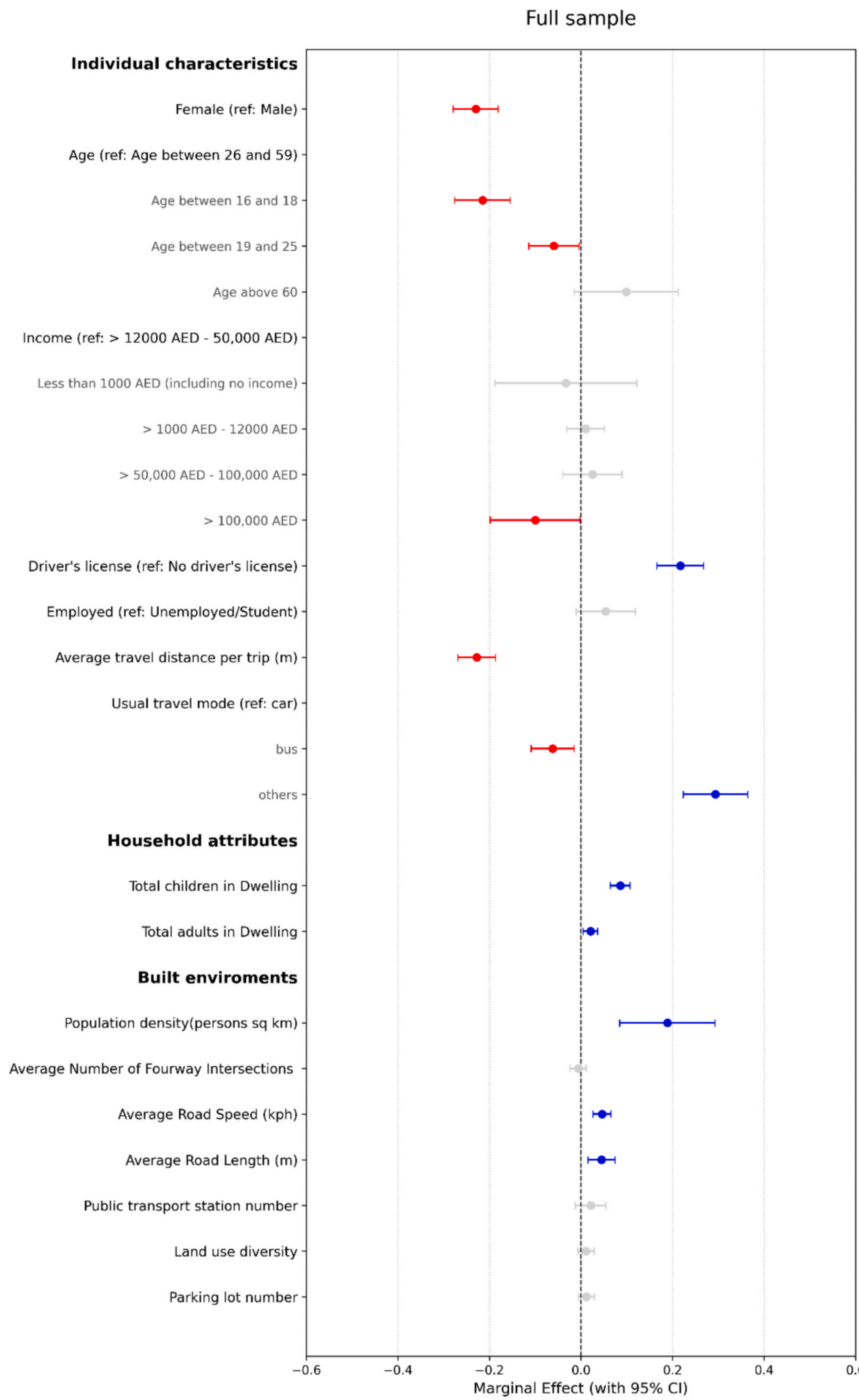


**Fig. 3.** Marginal effect: Full Sample. Note: Blue lines indicate statistically significant and positive marginal effects, red lines indicate statistically significant and negative marginal effects, and the light grey ones indicate insignificant effects. Error bars represent 95% confidence intervals. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

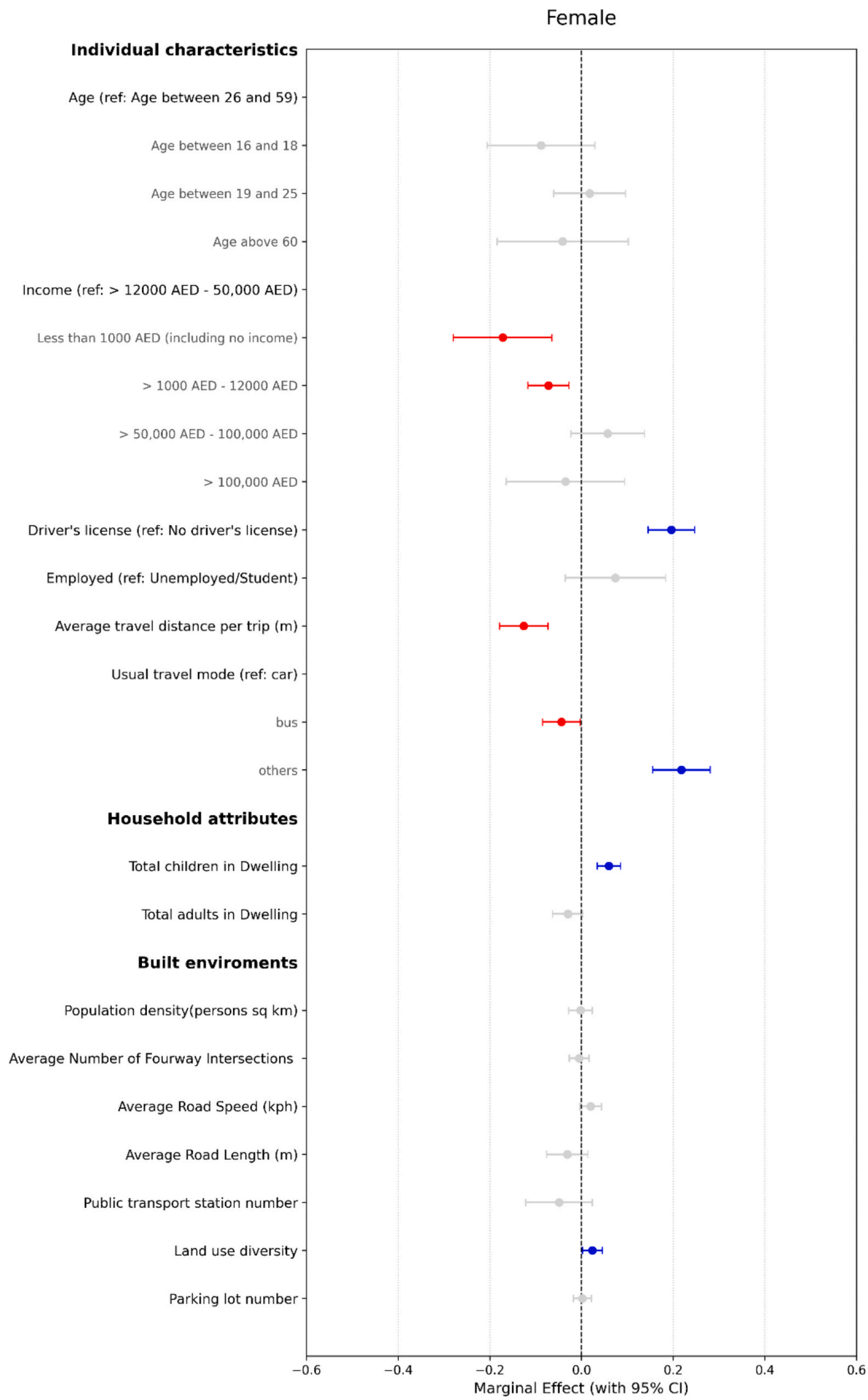


**Fig. 4.** Marginal effect: Gender Subsample. Panel A. Female. Note: Blue lines indicate statistically significant and positive marginal effects, red lines indicate statistically significant and negative marginal effects, and the light grey ones indicate insignificant effects. Error bars represent 95% confidence intervals. Panel B. Male. Note: Blue lines indicate statistically significant and positive marginal effects, red lines indicate statistically significant and negative marginal effects, and the light grey ones indicate insignificant effects. Error bars represent 95% confidence intervals. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

with greater land-use diversity. The positive association between land-use diversity and female trip chaining likely reflects improved accessibility to multiple activity destinations. The positive association between road speed, parking availability, and male trip chaining may reflect greater responsiveness to automobile-oriented infrastructure. Overall, female trip-chaining behavior appears to be more strongly influenced by socio-economic characteristics and less responsive to built-environment factors. In contrast, male trip chaining is influenced by both individual attributes and built-environment conditions.

*Heterogeneity analysis: driving ability and car dependence*

Access to transportation modes—particularly possession of a driver's license—plays a critical role in shaping trip-chaining behavior. Licensed drivers typically enjoy greater flexibility in scheduling and combining activities, particularly when commuting by private vehicle. In contrast, non-drivers are more reliant on other household members or public transportation, which may impose greater temporal and spatial constraints. To explore these differences, the sample is stratified by (1) driver's license status (drivers vs. non-drivers) and (2) primary mode use (private vehicle users vs. non-private vehicle users, including public transport and other modes). Columns 4–7 in Table 2 report the results of these heterogeneity analyses. As in the previous section, the discussion focuses primarily on marginal effects presented in Fig. 5, with reference to regression results in Table 2 where relevant.

Among individuals aged 16–18 without a driver's license and not using private vehicles, a negative relationship is observed with the number of intermediate stops. Similarly, individuals aged 19–25 with a driver's license report fewer stops. This may reflect educational commitments or early-career job demands that limit opportunities for intermediate activities. Additionally, many young adults in these age groups may not yet have family responsibilities, reducing the need for multi-purpose travel chains. An interesting pattern emerges regarding household composition. For non-licensed individuals and non-private vehicle users, an increase in the number of adults in the household is associated with more intermediate stops. In contrast, this relationship is not statistically significant for licensed drivers and private vehicle users, suggesting that mobility constraints may increase the need to combine errands among non-drivers.

Land-use diversity exhibits a statistically significant and positive marginal effect only among drivers (Fig. 5). However, decomposition of the ZINB model in Table 2 indicates that land-use diversity does not influence the propensity to engage in trip chaining but increases the number of intermediate stops among drivers and private vehicle users who already chain trips. This suggests that while land-use diversity does not affect the decision to chain trips among those with flexible mobility, it facilitates combining multiple activities once chaining occurs.

Built-environment features that favor private vehicle usage further illustrate differential effects, as suggested in Fig. 6. Increases in average road speed are positively associated with intermediate stops among both drivers and private vehicle users. A one SD increase in average road speed increases intermediate stops by 0.06 for drivers and 0.05 for private vehicle users. Faster travel speeds likely enhance the feasibility of linking multiple destinations within limited time constraints. Similarly, parking availability increases intermediate stops among drivers and private vehicle users. A one SD increase in parking supply increases intermediate stops by 0.03 for drivers and 0.07 for private vehicle users. Non-drivers and non-private vehicle users are comparatively less influenced by automobile-oriented infrastructure.

Public transportation infrastructure also exhibits heterogeneous effects. Marginal effects indicate that the number of public transport stations significantly affects only private vehicle users (Fig. 6). A one SD increase in transit stations within the residential TAZ reduces intermediate stops among private vehicle users by 0.07. This may reflect a substitution effect: individuals residing in transit-rich areas may shift certain discretionary trips to public transportation, reducing the need to chain stops via private vehicles.

However, the Negative Binomial component in Table 2 indicates that among non-private vehicle users who engage in trip chaining, a greater number of transit stations increases the number of intermediate stops. Thus, improved transit infrastructure does not alter the likelihood of engaging in trip chaining but may enable transit users to incorporate additional stops once chaining occurs.

Overall, the opportunity to increase intermediate stops among non-drivers and non-private vehicle users appears less sensitive to built-environment characteristics compared to licensed drivers and private vehicle users. Mobility flexibility and automobile access amplify responsiveness to infrastructure and land-use conditions.

**Discussion**

Building on existing trip-chaining research, this study provides new insights by examining a comprehensive set of demographic, socioeconomic, and built-environment determinants using travel survey data from Abu Dhabi. By incorporating heterogeneity analysis, the study offers a more nuanced understanding of how trip-chaining propensity and complexity vary across population subgroups. The findings provide policy-relevant evidence to support equitable mobility planning in global cities such as Abu Dhabi, which are characterized by highly diverse populations. Approximately 82% of respondents reported not engaging in trip chaining on the survey day. This high prevalence of non-chaining behavior suggests structural constraints in daily mobility patterns. It underscores the need to enhance public transportation accessibility, strengthen land-use integration, promote multimodal transportation corridors, and encourage sustainable travel modes.

The findings highlight the need for a targeted approach to support trip chaining among females. Traditional gender roles continue to influence women's mobility patterns in Abu Dhabi and, more broadly, in the UAE. Women's career progression and leadership opportunities may be constrained by prevailing social expectations related to marriage and family responsibilities (ENA, 2024). The heterogeneity analysis identifies employment status as a significant determinant of trip-chaining behavior among women. This finding is particularly relevant in light of national initiatives such as the "National Strategy for Empowerment of Emirati Women" (2015–2021), which aim to enhance women's participation in public and private sectors. The Ministry of Human Resources and Emiratisation (MoHRE) reported a 23.1% increase in women's participation in the private sector in 2023 compared to 2022 (Saeed, 2024). As women increasingly participate in the labor market, transportation systems must adapt to accommodate evolving travel needs. Policies that facilitate safe, flexible, and accessible multimodal options may support more efficient trip chaining among women, particularly working women balancing professional and household responsibilities.

The results indicate that longer travel distances reduce both the likelihood of trip chaining and the number of intermediate stops. Although trip chaining is less prevalent among public transit users, the reduction in intermediate stops with increasing travel distance is consistent across males and females, drivers and non-drivers, and private vehicle (PV) and non-PV users. This suggests that reducing travel distances may encourage trip chaining across population groups. Promoting work–play–shop proximity within residential areas can facilitate shorter trips and enhance opportunities for chaining activities. Mixed-use development has been shown to reduce automobile dependence and increase walking and cycling behavior (Eldeeb et al., 2021; Hatami et al., 2023), thereby minimizing the need for long-distance travel. These findings emphasize the importance of compact urban development and integrated land-use planning. Two major insights emerge from the predictive analysis.

First, trip-chaining behavior is strongly influenced by individuals' mobility options. Both the probability and complexity of trip chaining depend substantially on primary travel mode. Car users generate more

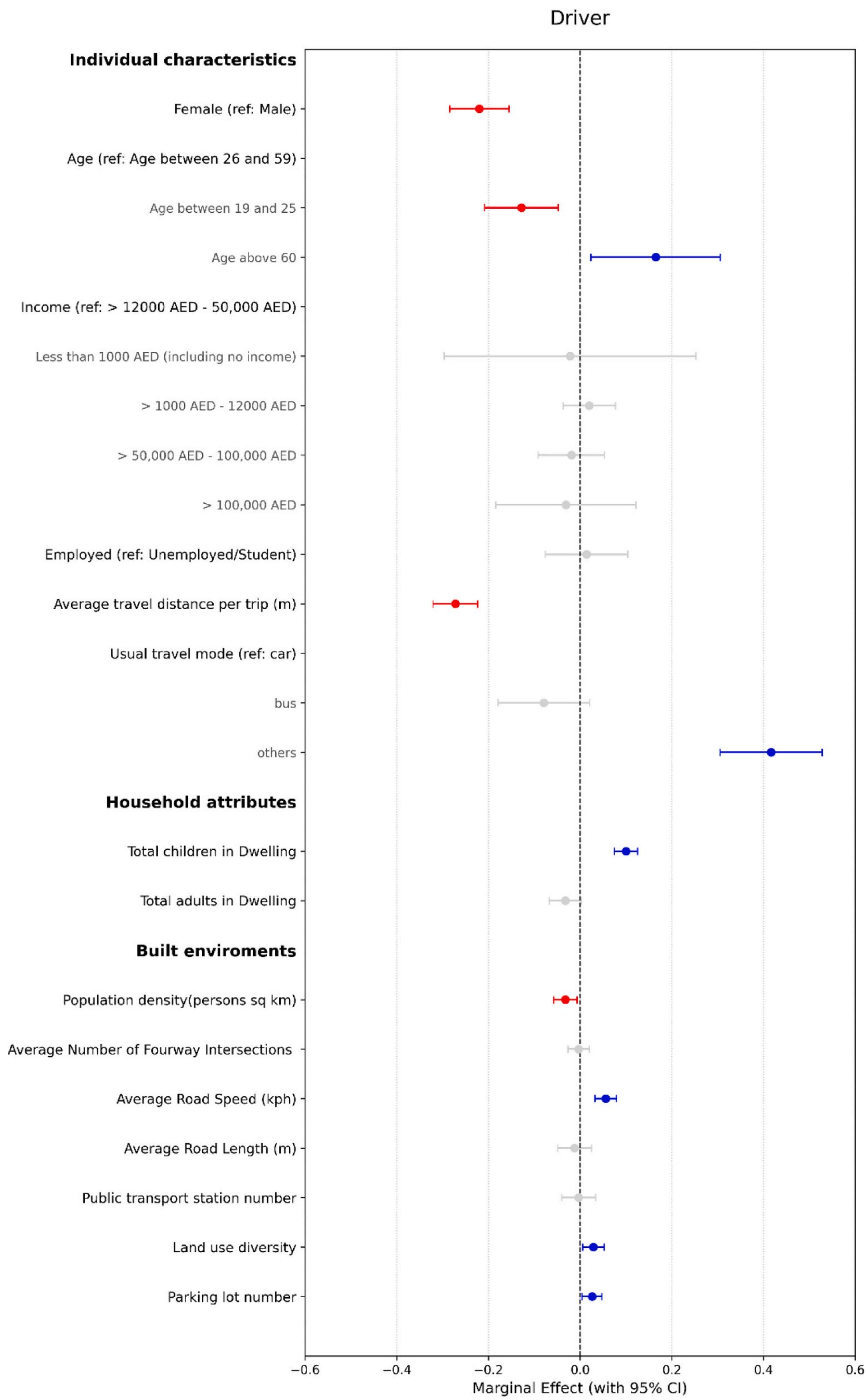


**Fig. 5.** Marginal effect: Driver's License Subsample. Panel A. Driver. Panel B. Non-Driver. Note: Blue lines indicate statistically significant and positive marginal effects, red lines indicate statistically significant and negative marginal effects, and the light grey ones indicate insignificant effects. Error bars represent 95% confidence intervals. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

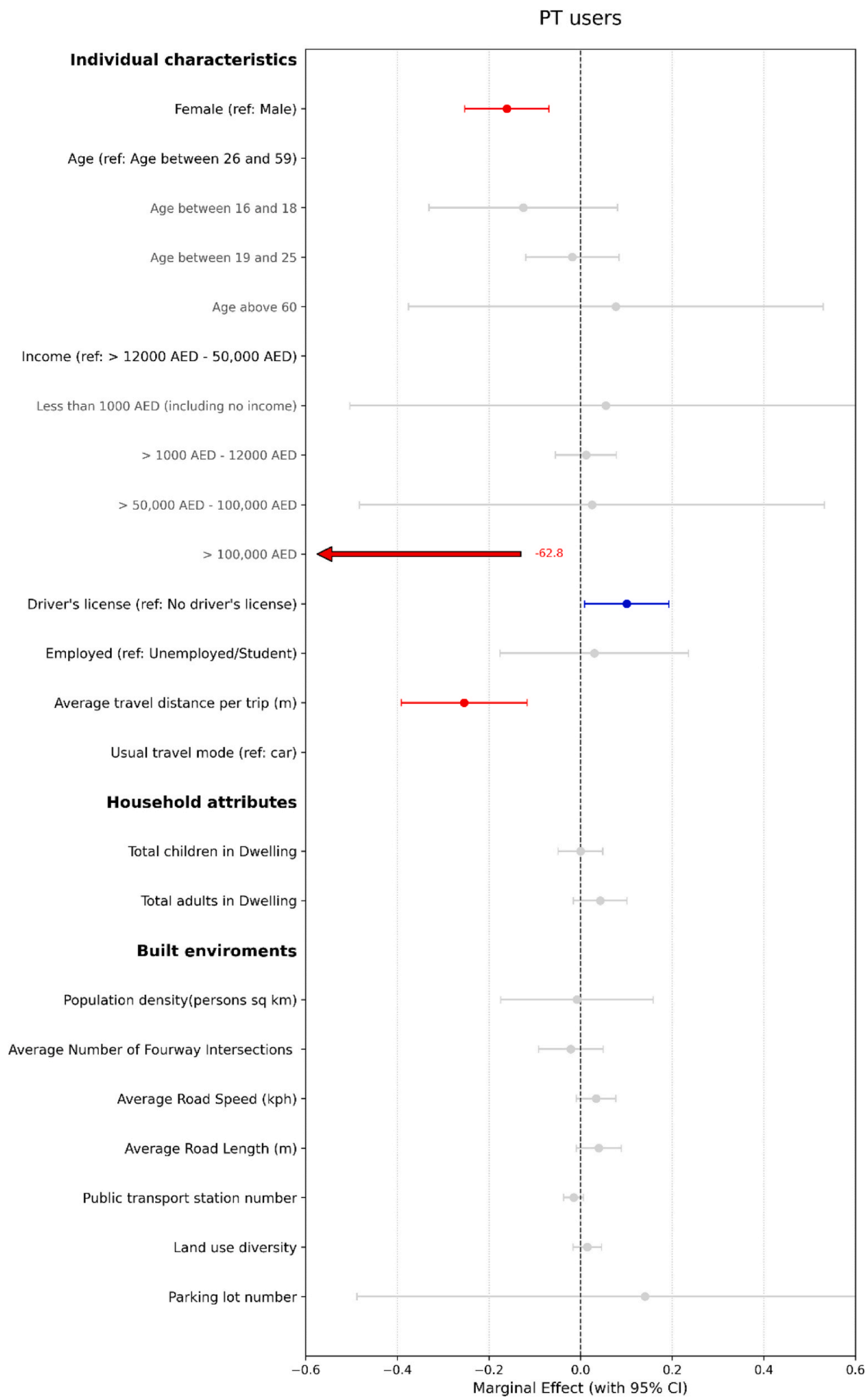


**Fig. 6.** Marginal effect: Daily Travel Mode Subsample. Panel A. Public Transit User. Panel B. Private Vehicle User. Note: Blue lines indicate statistically significant and positive marginal effects, red lines indicate statistically significant and negative marginal effects, and the light grey ones indicate insignificant effects. Error bars represent 95% confidence intervals. The marginal effect of income level at 100,000 AED is large compared to other variables and therefore compressed for the sake of clarity. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

chained trips than public transportation users. In the full sample, individuals relying primarily on public transit exhibit fewer intermediate stops on average, largely due to a lower likelihood of engaging in chaining behavior. The heterogeneity analysis further indicates that most built-environment features do not significantly influence trip chaining among individuals reliant on public transportation or other non-automobile modes. In contrast, automobile-oriented infrastructure—such as higher road speeds and greater parking availability—facilitates more complex trip chaining among drivers and PV users. These findings suggest that trip chaining in Abu Dhabi is constrained more by the relatively limited coverage and scheduling rigidity of public transportation than by land-use characteristics alone. In this context, Hasan et al. (2023) identified overcrowded buses and traffic congestion as key barriers to public transit usage, highlighting dissatisfaction with network coverage and service quality. The differential impact of mobility options on travel behavior carries important implications for urban planning. Enhancing the flexibility, coverage, and reliability of public transportation is critical if trip chaining is to shift toward more sustainable modes.

Second, the findings illuminate how interactions between the built environment and socioeconomic roles shape travel behavior. Neighborhood characteristics, particularly population density, exhibit subgroup-specific effects. While higher population density generally increases the number of intermediate stops, heterogeneity analysis reveals that density does not significantly influence trip-chaining behavior among females. This suggests that women's mobility patterns may be shaped more by sociocultural responsibilities, such as childcare and household duties, than by urban structure alone. Furthermore, employed females are more likely to engage in trip chaining but make fewer intermediate stops, reflecting time constraints associated with balancing work and domestic responsibilities. Policymakers should therefore consider how urban development and transport systems can better accommodate diverse social roles. As Abu Dhabi advances plans for denser, mixed-use neighborhoods (Abu Dhabi Urban Planning Council, 2007), efforts should prioritize improving public transport connectivity and operational flexibility. Complementary policies that encourage a more equitable distribution of unpaid care responsibilities may also enhance mobility opportunities, particularly for women.

This study contributes to understanding trip chaining in a car-dependent urban context and reveals travel patterns that differ from those documented in Western cities. Much of the existing literature has focused on contexts characterized by extensive transit infrastructure. In contrast, the findings here demonstrate that trip chaining in Abu Dhabi remains highly reliant on private vehicles, largely due to limitations in public transit coverage and flexibility.

This divergence has important policy implications. Research suggests that policymakers must account for contextual differences when designing transportation and land-use strategies (Hu and Li, 2021). Transit-oriented development (TOD) models successful in Western cities may not be directly transferable to Abu Dhabi without parallel investments in service frequency, coverage, and multimodal integration. As outlined in Plan Abu Dhabi 2030 – Urban Structure Framework Plan, reducing reliance on private vehicles remains a strategic objective. Achieving this goal will require sustained infrastructure investments and land-use policies that support frequent, reliable, and spatially extensive public transportation options. Only through such structural enhancements may trip-chaining patterns gradually shift toward lower-carbon modes.

Finally, this study provides a more holistic understanding of trip-chaining determinants by integrating individual, household, and built-environment factors within a single analytical framework. The heterogeneity analysis reveals nuanced and sometimes opposing effects—such as differential density impacts—that may be overlooked in aggregate models. Although cross-sectional in design, the study underscores the importance of incorporating socioeconomic heterogeneity when developing transportation policies. The findings suggest that transportation authorities should pursue flexible, user-centred solutions that address diverse mobility needs. By reducing travel times and enhancing service adaptability, public transportation can become a more viable and attractive alternative for a broader segment of residents.

## Conclusion and implications

This study examined the trip-chaining behavior of residents in Abu Dhabi, UAE, using data from the most recent transportation survey conducted in 2015. In a highly multicultural city such as Abu Dhabi—where expatriates constitute over 88% of the population—transportation management strategies that enhance land use–transportation integration, reduce vehicle miles traveled (VMT), and promote alternative travel modes can benefit from context-specific policy interventions. The findings of this study offer several actionable insights for transportation agencies seeking to address trip-chaining behavior.

### *Inclusive planning*

Policymakers should adopt inclusive planning approaches that account for the diverse mobility needs of different population groups, including females, public transit users, non-workers, and various age cohorts. Urban development and transportation systems should be designed to support accessibility for all community members, particularly individuals with caregiving responsibilities or limited access to private vehicles. Enhancing land-use diversity and improving access to essential services—both in urban cores and suburban neighborhoods—may facilitate trip chaining by enabling individuals to combine multiple activities within a single tour. In addition, ensuring adequate parking availability in strategically designated activity centers may support drivers and private vehicle users in consolidating daily errands, thereby increasing the likelihood of trip chaining. Such considerations should be incorporated into planning strategies led by the Urban Planning Council in Abu Dhabi.

### *Enhancing the public transit system*

Given the strong reliance on private vehicles—largely attributable to limitations in Abu Dhabi's public transportation network—substantial investments in transit infrastructure are required. This includes expanding network coverage, increasing service frequency, and enhancing multimodal connectivity. Public transportation must be made more convenient, reliable, and flexible to compete effectively with private car use. Although public transportation has been identified in some studies as a potential impediment to trip chaining (Cheng et al., 2016), targeted policy measures may mitigate this effect. For example, the Integrated Transportation Centre (ITC) in Abu Dhabi introduced a unified fare of AED 5 (USD 1.36) in December 2023 for passengers requiring multiple bus transfers, eliminating additional transfer charges. Such fare integration policies can encourage more flexible transit use. Similarly, expanding subsidized Hafilat Cards for low-income residents may facilitate trip chaining among transit-dependent users, particularly for non-work-related travel.

### *Encouraging sustainable transportation*

As Abu Dhabi aims to reduce dependence on private vehicles and promote sustainable mobility, infrastructure investments and land-use policies should prioritize non-motorized transportation. Urban planning initiatives should encourage public transport use, walking, and cycling through supportive infrastructure and policy incentives. Empirical evidence suggests that active transportation modes—including walking, cycling, and public transit—can increase the likelihood of trip chaining by more than 40% (Schneider et al., 2021). Policy instruments such as congestion pricing, parking management strategies, and public transit subsidies may further incentivize shifts toward sustainable modes. Integrating pedestrian- and cyclist-friendly infrastructure within mixed-use neighborhoods can reduce travel distances and support environmentally sustainable trip-chaining patterns.

*Integrated land use and transportation planning*

Effective integration of land use and transportation planning is essential to create sustainable and livable communities. Coordinated land-use and transportation policies can reduce automobile dependency, shorten travel distances, and promote compact, mixed-use development. Such development patterns enable individuals to complete multiple activities within shorter distances, thereby facilitating trip chaining through more sustainable modes. Pokharel et al. (2023), in a system-level analysis aimed at breaking the "vicious circle" of car dependency (Newman and Kenworthy, 1999), emphasize three key strategies directly aligned with the findings of this study: (1) high-density-oriented development, (2) infrastructure investment to support sustainable modes of travel, and (3) strategic allocation of resources to encourage alternative transportation options. These recommendations are particularly relevant for Abu Dhabi's long-term urban sustainability objectives.

*Limitations and future research*

Despite its contributions, this study has several limitations. First, the data were collected in 2015. Although travel surveys are typically conducted at decadal intervals, travel patterns may have shifted in response to structural changes, including the COVID-19 pandemic. Updated survey data would allow for a more accurate assessment of evolving travel behaviors.

Second, due to privacy regulations, precise origin and destination locations were not available for analysis. While aggregated TAZ-level data were used, more detailed spatial information could enable refined distance calculations and more location-specific policy recommendations. Nevertheless, it is unlikely that the direction and statistical significance of the main determinants would substantially differ with more granular spatial data. Future research incorporating micro-level spatial data could generate more precise, neighborhood-specific insights to inform transportation planning in Abu Dhabi and the broader UAE context.

Notwithstanding these limitations, this study underscores the importance of addressing the multifaceted determinants of trip-chaining behavior in Abu Dhabi, including mobility options, built-environment characteristics, and socioeconomic roles. The findings reveal that trip chaining remains strongly influenced by automobile access and constrained by public transit limitations, while also reflecting heterogeneous effects across gender and socioeconomic groups. By implementing targeted, evidence-based policies—particularly those enhancing transit flexibility, integrating land use and transportation planning, and promoting inclusive mobility—policymakers can work toward a more sustainable, equitable, and resilient transportation system that accommodates the diverse needs of Abu Dhabi's population.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work the author(s) used ChatGPT to improve the language and structure of the manuscript after peer-review and provisional acceptance of the article. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

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## CRediT authorship contribution statement

**Praveen Maghelal:** Writing – review & editing, Writing – original draft, Supervision, Formal analysis, Conceptualization. **Yuqing Guo:** Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis, Conceptualization. **Xuan Zhang:** Writing – review & editing, Writing – original draft. **Pengyu Zhu:** Writing – review & editing, Supervision, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix

**Table A1**
ZINB results: Marginal effects.

| | Full sample | Female | Male | Non-Driver | Driver | Non-car users | PV users |
|---|---|---|---|---|---|---|---|
| *Individual characteristics* | | | | | | | |
| Female (ref: Male) | −0.230*** | | | −0.195*** | −0.220*** | −0.234*** | −0.218*** |
| | (0.025) | | | (0.033) | (0.033) | (0.037) | (0.032) |
| Age (ref: Age between 26 and 59) | | | | | | | |
| Age between 16 and 18 | −0.215*** | −0.088 | −0.252*** | −0.123*** | | −0.280*** | −0.015 |
| | (0.031) | (0.060) | (0.048) | (0.027) | | (0.040) | (0.138) |
| Age between 19 and 25 | −0.059* | 0.018 | −0.118** | −0.007 | −0.128** | −0.079 | −0.002 |
| | (0.028) | (0.040) | (0.038) | (0.030) | (0.041) | (0.042) | (0.051) |
| Age above 60 | 0.099 | −0.041 | 0.189* | 0.002 | 0.165* | −0.040 | 0.208** |
| | (0.058) | (0.073) | (0.076) | (0.072) | (0.072) | (0.059) | (0.071) |
| Income (ref: > 12,000 AED − 50,000 AED) | | | | | | | |
| Less than 1,000 AED (including no income) | −0.033 | −0.172** | 0.053 | −0.026 | −0.022 | −0.057 | 0.032 |
| | (0.079) | (0.055) | (0.109) | (0.079) | (0.140) | (0.078) | (0.173) |
| > 1,000 AED – 12,000 AED | 0.010 | −0.072** | 0.048 | −0.030 | 0.020 | −0.020 | 0.050 |
| | (0.021) | (0.023) | (0.028) | (0.028) | (0.029) | (0.031) | (0.027) |
| > 50,000 AED − 100,000 AED | 0.025 | 0.057 | −0.054 | 0.038 | −0.019 | 0.031 | −0.024 |
| | (0.033) | (0.041) | (0.036) | (0.064) | (0.037) | (0.049) | (0.044) |
| > 100,000 AED | −0.100* | −0.035 | −0.124 | −0.166* | −0.031 | 0.014 | −0.138 |

(continued on next page)

**Table A1** (*continued*)

| | Full sample | Female | Male | Non-Driver | Driver | Non-car users | PV users |
|---|---|---|---|---|---|---|---|
| | (0.050) | (0.066) | (0.072) | (0.067) | (0.078) | (0.103) | (0.093) |
| Driver's license (ref: No driver's license) | 0.217*** | 0.196*** | 0.184*** | | | 0.289*** | −0.023 |
| | (0.026) | (0.026) | (0.040) | | | (0.033) | (0.058) |
| Employed (ref: Unemployed/Student) | 0.054 | 0.074 | 0.059 | 0.081 | 0.014 | −0.020 | 0.303*** |
| | (0.033) | (0.056) | (0.048) | (0.046) | (0.046) | (0.036) | (0.088) |
| Average travel distance per trip (m) | −0.228*** | −0.126*** | −0.298*** | −0.180*** | −0.272*** | −0.249*** | −0.223*** |
| | (0.021) | (0.027) | (0.026) | (0.036) | (0.025) | (0.032) | (0.026) |
| Usual travel mode (ref: car) | | | | | | | |
| bus | −0.062** | −0.044* | −0.058 | −0.074** | −0.079 | | |
| | (0.024) | (0.021) | (0.037) | (0.026) | (0.051) | | |
| others | 0.294*** | 0.218*** | 0.306*** | 0.109** | 0.417*** | 0.238*** | |
| | (0.036) | (0.032) | (0.048) | (0.038) | (0.057) | (0.029) | |
| *Household attributes:* | | | | | | | |
| Total children in Dwelling | 0.086*** | 0.060*** | 0.095*** | 0.036** | 0.100*** | 0.063*** | 0.090*** |
| | (0.011) | (0.013) | (0.012) | (0.013) | (0.013) | (0.014) | (0.012) |
| Total adults in Dwelling | 0.021** | −0.030 | 0.036*** | 0.025*** | −0.032 | 0.042*** | −0.032 |
| | (0.008) | (0.017) | (0.010) | (0.007) | (0.018) | (0.010) | (0.023) |
| *Built environments:* | | | | | | | |
| Population density(persons sq km) | 0.189*** | −0.002 | −0.047*** | −0.035** | −0.032* | −0.051*** | −0.020 |
| | (0.053) | (0.013) | (0.014) | (0.013) | (0.013) | (0.015) | (0.013) |
| Average Number of Fourway Intersections | −0.006 | −0.005 | 0.002 | 0.003 | −0.003 | −0.014 | 0.006 |
| | (0.009) | (0.011) | (0.013) | (0.012) | (0.012) | (0.014) | (0.012) |
| Average Road Speed (kph) | 0.046*** | 0.020 | 0.060*** | 0.022 | 0.056*** | 0.018 | 0.054*** |
| | (0.010) | (0.012) | (0.012) | (0.012) | (0.012) | (0.014) | (0.012) |
| Average Road Length (m) | 0.045** | −0.031 | 0.011 | 0.020 | −0.012 | 0.046* | −0.010 |
| | (0.015) | (0.023) | (0.017) | (0.015) | (0.019) | (0.019) | (0.028) |
| Public transport station number | 0.021 | −0.049 | −0.016 | 0.014 | −0.003 | 0.016 | −0.073** |
| | (0.017) | (0.037) | (0.015) | (0.024) | (0.019) | (0.015) | (0.025) |
| Land use diversity | 0.011 | 0.024* | 0.020 | 0.006 | 0.029* | 0.022 | 0.017 |
| | (0.009) | (0.011) | (0.012) | (0.011) | (0.012) | (0.013) | (0.011) |
| Parking lot number | 0.012 | 0.002 | 0.037* | 0.121 | 0.026* | 0.006 | 0.065*** |
| | (0.009) | (0.010) | (0.016) | (0.062) | (0.011) | (0.017) | (0.020) |
| Observations | 9052.000 | 3317.000 | 5735.000 | 3387.000 | 5665.000 | 3950.000 | 5102.000 |

Standard errors in parentheses; *p $<$ 0.05, **p $<$ 0.01, ***p $<$ 0.001.

## Data availability

The authors do not have permission to share data.

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