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Assessing the Impact of Individuals' Social Characteristics and Functional Aspects of Tehran's Metro on the Choice of Travel Pattern

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A B S T R A C T

Rapid urbanization, driven by industrial development and growing automobile dependency, has led to imbalanced urban expansion, traffic congestion, and extended travel times. As Tehran, the capital of Iran, continues to grow, this study examines urban travel patterns to inform sustainable mobility and transportation planning. The primary objective is to assess how individuals' social characteristics and the functional attributes of Tehran's metro system influence travel mode choice.

A mixed-methods approach was employed, integrating qualitative and quantitative data collected through surveys and questionnaires. A Mixed Logit Model was used to analyze travel mode choice for commuting between home and workplace. The analysis revealed two major categories of influencing factors: (1) socio-economic characteristics and (2) functional aspects of metro services. Among the statistically significant variables, gender, age, metro travel time, and perceived vitality/productivity positively influenced metro usage, with marginal effects of 0.1088, 0.240, 0.0036, and 0.1429, respectively. While other variables were statistically insignificant, their signs were consistent with theoretical expectations.

The findings provide critical insights into travel behavior in Tehran and enhance the understanding of metro use as a component of sustainable urban transport systems.

- *Travel time, cost savings, and ease of movement between home and workplace are significantly associated with individuals' travel pattern choices.*
- *Visibility of metro stations, continuity and quality of sidewalks, proximity to stations, and the availability of bicycle parking facilities significantly affect willingness to use the metro.*
- *Although the metro contributes to reducing private vehicle use, car ownership does not have a statistically significant effect on travel mode choice for commuting.*

1. INTRODUCTION

Urban sprawl and the increasing reliance on private vehicles have led to a significant rise in travel by personal cars. This trend has resulted in greater traffic congestion, higher fuel consumption, environmental pollution, and broader negative impacts on society—not only environmental but also social and economic (Galelo *et al.*, 2014; Bento *et al.*, 2005; Brand & Fry, 2004). In essence, current urban growth patterns, combined with socio-cultural factors, have contributed to longer commutes and growing car dependency, thereby exacerbating pressure on the environment and urban systems (Hasibuan *et al.*, 2014; Schwanen *et al.*, 2001).

Additionally, in today's rapidly expanding cities, the demand for mobility and travel time continues to increase due to the spatial dispersion of activities. This often makes reliance on personal vehicles inevitable (Ghanbari *et al.*, 2010; Ghadami & Nabi Nejad Konari, 2011; Effandi Zadeh & Hajian, 1999). Urban decentralization and car dependency have lengthened trip distances and intensified urban sprawl, contrary to efforts to achieve compact urban forms (Abbasi & Hajipour, 2014; Abolhassani, 2003; Mozayeni, 2001). Nevertheless, the "automobility regime" continues to dominate urban travel in many regions (Puhe & Schippl, 2014), and car ownership remains a major determinant of carbon emissions from individual transport (Susnienė, 2012).

From a socioeconomic standpoint, traffic congestion results in significant time loss, which reduces productivity

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and has adverse economic consequences (Social Research Unit, Tehran Metro Technical Faculty, 1994). Accordingly, rethinking urban access methods and prioritizing public transport, pedestrian infrastructure, and cycling over private vehicle use has become a core principle in modern urban design (Frey, 2003).

Travel mode choice significantly impacts economic, social, psychological, and environmental outcomes, as well as citizen access to urban services (Ghadami & Nabi Nejad Konari, 2011; Grazi & Bergh, 2008). Individuals with a habitual reliance on cars are less likely to consider alternative modes of transport (Susnienė, 2012). Thus, improving public transport quality is a central priority in transport policy.

The concepts of sustainable development and sustainable transportation have gained increasing attention in recent decades (Russo & Comi, 2011). According to Banister (2008), achieving sustainable urban transport requires three key strategies: deploying cleaner technologies, promoting more efficient modes of transport, and reducing overall travel demand. Promoting walking, cycling, and public transit as environmentally beneficial alternatives helps challenge the social prestige associated with car ownership (Nasrudin *et al.*, 2013).

From a planning perspective, encouraging a shift from private to public transport modes through transit-oriented development (TOD) is widely seen as a viable solution (Lee & Lee, 2014). TOD planning is increasingly endorsed by urban and transportation planners as a means to reduce car dependency and promote sustainable mobility (Chow, 2014).

Public mass transit systems such as metro and light rail can significantly alter travel behavior (Deng & Nelson, 2011). Research shows that rail-based transit systems transform both land use and travel patterns (Chow, 2014). Understanding the interaction between travel patterns and users' social characteristics can inform traffic policies and strategies aimed at reducing car dependency (Choi *et al.*, 2014; Loukopoulos, 2005).

In Tehran, like many cities in developing countries, increased vehicle ownership and urban population growth have led to serious challenges, including congestion, rising accident rates, air pollution, and prolonged travel times (Milani & Haddadi, 2012). The concentration of administrative and commercial centers in central Tehran exacerbates these issues, creating intense travel demand and a need for extensive car parking facilities that the city struggles to provide (Abbas Zadegan *et al.*, 2010).

Tehran's socio-economic diversity also contributes to a variety of travel behaviors. The city's vast area increases travel time between home and workplace, making public transport a cost- and time-efficient choice for many. To curb car use, the city has implemented policies like the "even-odd" traffic scheme in central areas, which influences residents' travel patterns—particularly their choice of transport mode, destination, and frequency of trips (Pourahmad *et al.*, 2014).

Given these dynamics, this study explores how socio-demographic and functional factors influence travel mode choices along Line 1 of the Tehran Metro. It seeks to evaluate how such variables shape the daily commute between home and workplace, with a view toward sustainable transportation planning.

2. LITERATURE REVIEW

Understanding and modeling travel demand remains a core concern in transportation research and planning (Zhang *et al.*, 2017). Travel demand is influenced by a combination of socio-economic variables, infrastructure quality, and service attributes such as cost and comfort (Webster & Bly, 1980; Paulley *et al.*, 2006). In cities like Haifa, travel cost was identified as a key driver in encouraging public transport use (Sharaby & Shiftan, 2012), while similar findings apply to university students' mode choices in India (Nasrin, 2017).

In recent years, researchers have increasingly focused on user satisfaction, which influences loyalty to public transport systems (Lam *et al.*, 2004; Eboli & Mazzulla, 2009). Studies show that fare increase reduce ridership and satisfaction levels (Zhang *et al.*, 2017).

Urban structure and land use significantly affect travel behavior. Spatial dispersion, job-housing mismatch, and urban form factors such as density and compactness all shape travel patterns (Rahman, 2020; Liu et al., 2020). The variability in travel needs and habits emphasizes the importance of tailored public transport policies. Trip frequency, timing, and purpose are core dimensions of travel behavior (McGuckin & Murakami, 1999; Noland & Polak, 2002; Murray-Tuite & Mahmassani, 2003).

Socio-demographic factors—particularly age, gender, occupation, and education—play a critical role in shaping travel behavior. For example, women are typically more reliant on public transit and walk more often than men, especially in developing countries with limited transit infrastructure (Polk, 2004; Pourhashem *et al.*, 2019; Mahadevia & Advani, 2016). Age also influences travel distance and mobility, particularly among the elderly (Priya *et al.*, 2020).

Environmental and built environment variables—including urban density, proximity to transit, and land use diversity—also shape mode choice (Schwanen *et al.*, 2001; Souche, 2010; Nakshi *et al.*, 2020). Several studies confirm that built environmental factors like accessibility and land-use mix correlate with reduced car use and increased public transport patronage (Bagley & Mokhtarian, 2002; Boarnet & Crane, 2001; Chow, 2014).

Importantly, travel patterns are also influenced by subjective variables—individual preferences, attitudes, lifestyle, and environmental norms (Nordlund et al., 2003; Kitamura, 2009; Ababio-Donkor *et al.*, 2020). Researchers argue that controlling psychological variables can improve the accuracy of travel behavior modeling (Van Acker *et al.*, 2011).

Studies have also highlighted the relationship between life events and mobility changes. Events like employment changes, relocation, or family transitions can serve as turning points in travel behavior (Chatterjee *et al.*, 2013; Clark *et al.*, 2014; Grandsart, 2020). However, individuals who rely on a single travel mode tend to resist

behavioral changes compared to multimodal travelers (De Haas *et al.*, 2018).

Although extensive research exists on the effects of built environment and urban form in developed countries—especially North America—fewer studies have examined these dynamics in the South Asian context, including Iran (Abbasi & Hajipour, 2012; Abbasi *et al.*, 2012). This study seeks to fill that gap by examining how both social and functional factors affect travel choices in Tehran.

3. METHODOLOGY

This research adopts a mixed-methods approach, combining both qualitative and quantitative strategies to assess the impact of social characteristics and functional aspects of Tehran's metro system on the choice of travel pattern. The primary objective is to analyze how different socio-economic factors and metro-related functional variables influence citizens' mode choices—particularly between home and workplace—along Line 1 of the Tehran Metro.

A. Study Area

The study was conducted in the vicinity of three stations along Line 1 of the Tehran Metro. These areas were selected due to their high commuter volume, diverse demographic characteristics, and strategic importance in connecting residential zones to central business districts. The selected stations represent both high- and middle-density urban environments, enabling a broader understanding of travel behavior across different socio-spatial contexts in Tehran.

B. Data Collection

Datasets were collected through structured questionnaires distributed among metro users at the selected stations. The questionnaire consisted of three main sections:

- Demographic and Social Characteristics: age, gender, income level, education, employment status, and car ownership.
- Travel Behavior Information: origin-destination, purpose of trip, travel frequency, time of day, and preferred mode of transportation.
- Functional Aspects of Metro Usage: accessibility to metro stations, travel time, cleanliness, comfort, safety, frequency of service, and perceived efficiency compared to other modes.

A stratified random sampling technique was used to ensure a balanced representation of gender, age groups, and socio-economic classes. The sample size included 450 respondents, distributed evenly across the three study sites. The data collection process was conducted during peak and off-peak hours to capture variability in travel behavior.

C. Analytical Framework

To evaluate the factors influencing travel pattern choice, a Mixed Logit Model (MLM) was employed. The Mixed Logit Model is suitable for discrete choice analysis as it allows for random variations in preferences across individuals and accommodates correlation in unobserved factors over alternatives.

The utility function in the model was specified as follows:

$$U_{ij} = \beta X_{ij} + \varepsilon_{ij}$$

Where:

- U_{ij} is the utility that individual *i* derives from choosing alternative *j*,
- X_{ij} is a vector of observed variables (social and functional),
- β is a vector of parameters to be estimated,
- ε_{ij} is a random error term.

The dependent variable is the choice of mode (metro versus other transport modes) for commuting to work. Independent variables were grouped into two categories:

1. Socio-economic variables (e.g., age, gender, education, income)
2. Functional attributes of metro service (e.g., travel time, accessibility, safety, and user satisfaction)

The model was estimated using maximum likelihood estimation techniques. Statistical significance was tested at 95% and 99% confidence intervals, and goodness-of-fit measures (e.g., log-likelihood, pseudo R-squared) were calculated to assess model performance.

D. Ethical Considerations

All participants were informed about the purpose of the study and gave their informed consent before participating in the survey. Data confidentiality and respondent anonymity were strictly maintained throughout the study in compliance with ethical research standards.

E. Method

This study adopts a mixed-method approach, incorporating both quantitative and qualitative methodologies. Data collection was conducted through structured surveys and questionnaires, and analytical evaluation was carried out using the Mixed Logit Model via Stata software. The model investigates the relationship between individuals' mode choice for

commuting via metro and a set of socio-economic and functional variables.

The Mixed Logit Model was chosen for its flexibility in accommodating random utility, taste heterogeneity, and unrestricted substitution patterns, overcoming the limitations of traditional multinomial and probit models (Train, 2009). It calculates the probability of choosing a travel option based on a utility function:

$U_{ni} = V_{ni} + \varepsilon_{ni}$

where:

- V_{ni} is the observable utility,
- ε_{ni} is the unobservable/random component, further modeled as:

$P_{ni} = \int L_{ni}(\beta) f(\beta) d\beta$

Variables included:

- Socio-economic: gender, age, income, education, car ownership, driver's license
- Functional: metro travel time, accessibility, ease of commuting, productivity, vitality

Study Area:

Three stations from Line 1 of Tehran Metro were selected:

- Tajrish (North) – low to medium density (95 ppl/ha)
- Mirdamad (Central) – medium density (110 ppl/ha)
- Khayam (South) – high density (150 ppl/ha)

A buffer radius of 800 meters was defined around each station for spatial analysis. Based on Tehran's 2017 census data, a population of 71,340 resides in these areas. Using Cochran's formula, 383 questionnaires were randomly distributed across these zones among residents and workers.

F. Case Study: Tehran Metro

Tehran, Iran's capital with a population of over 8.6 million (Statistical Center of Iran, 2016), experiences more than 17 million daily car trips, leading to serious urban congestion, time loss (~180,000 hours/day), and environmental degradation (Tehran Municipality, 2012).
The city's metro project was conceived in 1958 but only gained traction after 1986. The Line 1 metro runs from Tajrish to Behesht-e-Zahra, spanning 34.3 km (14.9 km underground, 19.4 km above ground) and includes 27 stations.

Key station profiles:

- Tajrish: affluent, cultural and recreational hub
- Mirdamad: office-dense, commercial and religious facilities
- Khayam: older central area with lower socio-economic indicators

These stations represent diverse social and spatial contexts, offering a comparative analysis of metro usage based on differing urban structure and class dynamics.

4. FINDINGS AND RESULTS

According to Figure 5.1, metro usage for commuting between home and workplace is higher than other transportation modes across all three stations studied. Among them, Tajrish Station shows the highest share of metro users, with 50% of respondents indicating metro as their primary mode of travel. Additionally, 16% of respondents reported using Bus Rapid Transit (BRT) or standard bus services. The highest proportion of BRT users was recorded at Mirdamad Station, where there is also a notable presence of multimodal travel patterns—such as metro-BRT and metro-taxi combinations.

At Khayam Station, taxi usage ranks second after the metro, accounting for 28% of respondents. This can be attributed to the absence of BRT services in the surrounding area and the station's location within Tehran's traffic-restricted zone. Consequently, Khayam also exhibits a higher frequency of combined transportation patterns involving metro and alternative modes, compared to the other two stations (Table 5.1).

Table 5.1 Personal Property and Its Impact on Metro Usage

A. Having Driver's License

Metro Station	Yes (Count)	Yes (%)	No (Count)	No (%)	Total
Tajrish	89	68%	41	32%	130
Mirdamad	95	73%	35	27%	130
Khayam	87	67%	43	33%	130
Total	271	69%	119	31%	390

B. Using Metro Due to Not Having a Driver's License

Metro Station	Yes (Count)	Yes (%)	No (Count)	No (%)	Total
Tajrish	13	10%	117	90%	130
Mirdamad	13	10%	117	90%	130
Khayam	11	8%	119	92%	130

Metro Station	Yes (Count)	Yes (%)	No (Count)	No (%)	Total
Total	37	9%	353	91%	390

C. Having Personal Vehicle

Metro Station	Yes (Count)	Yes (%)	No (Count)	No (%)	Total
Tajrish	50	38%	80	62%	130
Mirdamad	56	43%	74	57%	130
Khayam	56	43%	74	57%	130
Total	163	42%	227	58%	390

D. Effectiveness of Metro in Reducing Personal Vehicle Use

Metro Station	Yes (Count)	Yes (%)	No (Count)	No (%)	Total
Tajrish	108	83%	22	17%	130
Mirdamad	115	88%	15	12%	130
Khayam	117	90%	13	10%	130
Total	340	87%	50	13%	390

E. Having Dedicated Car Parking Space

Metro Station	Yes (Count)	Yes (%)	No (Count)	No (%)	Total
Tajrish	76	60%	52	40%	130
Mirdamad	76	58%	54	42%	130
Khayam	76	60%	52	40%	130
Total	232	59%	158	41%	390

4.1. Socio-Demographic Aspects of Travel Patterns

In terms of gender, metro usage is higher among male respondents, likely due to a greater proportion of males being employed and actively commuting between home and workplace.

A substantial majority of metro users (76%) fall within the 18–35 age group, followed by 11% in the 36–45 age group. This reflects the higher public transport dependency among the younger, economically active population.

Income level analysis shows that 47% of respondents belong to the low-income group, and 41% to the middle-income group, whereas individuals in the high-income group demonstrate less willingness to use public transportation.

Timesaving and avoiding traffic congestion were cited as the primary motivations for using the metro by 70% of respondents. These factors are especially influential in areas like Khayam, which experiences severe traffic congestion and access limitations due to its central location within Tehran's restricted traffic zone.

Regarding personal mobility characteristics:

- 69% of respondents across all stations possess a driver's license, while 31% do not.
- Only 9% reported using the metro because they lack a driver's license. In other words, the vast majority (91%) use the metro for reasons other than license possession.

The ownership of private vehicles also influences metro usage:

- 58% of metro users do not own a personal vehicle, while 42% do.
- Despite owning cars, many respondents still prefer metro commuting due to the factors mentioned above.
- Tables 5.1 and 5.2 confirm that metro use is significantly associated with reduced reliance on private vehicles, with 87% of respondents across all stations acknowledging a decrease in their car usage. This effect is most pronounced at Khayam Station, likely due to its location within the city's traffic-controlled zone.

Additionally, 41% of respondents reported not having a dedicated parking space for their personal vehicle. Although around 60% do have private parking access, a significant portion of them—around 20%—do not own vehicles, suggesting that vehicle ownership may be more burdensome than beneficial for some commuters, thus reinforcing their preference for public transit.

Table 5.2 Personal Vehicle Ownership and Metro Usage Characteristics

Criteria	Tajrish	Mirdamad	Khayam	Total
Driver's License (%)	68% Yes	73% Yes	67% Yes	69% Yes
Using Metro due to No License (%)	10%	10%	8%	9%
Own Personal Vehicle (%)	38%	43%	43%	42%
Metro Reduced Vehicle Use (%)	83%	88%	90%	87%

Criteria	Tajrish	Mirdamad	Khayam	Total
Have Dedicated Parking (%)	60%	58%	60%	59%

4.2. Functional Aspects of Travel Patterns

Analysis of respondents' views (Table 5.2) reveals that the metro system significantly facilitates movement between home and workplace. A substantial 79% of respondents reported a high level of effectiveness in this regard. This perception is most prominent at Khayam Station (83%), compared to Mirdamad (78%) and Tajrish (76%). The higher satisfaction at Khayam may stem from its central location in District 12 of Tehran, which is heavily impacted by traffic congestion and restrictions, making metro use more critical. By contrast, only 6% of respondents reported a low effectiveness of the metro in facilitating their commute.

Regarding access to urban facilities, approximately 60% of respondents across all stations believed that the metro significantly improved their accessibility. The effect is most pronounced in Tajrish Station (67%), likely due to its location in northern Tehran, which is relatively distant from many city-center services. Thus, the metro has played a key role in bridging this spatial gap. In contrast, only a small minority (less than 10%) across all stations perceived the metro as having a low impact on facility access.

Additionally, 62% of respondents believed that the metro had a moderate to high effect on improving their vitality and daily efficiency. In Tajrish Station, 42% of respondents reported a *very high* impact, followed by 38% in Khayam and 25% in Mirdamad. This impact in Khayam may relate to its proximity to the Tehran Bazaar, which increases daily activity and market visits. These results underscore the metro's role in enhancing urban vitality, particularly in commercial and high-traffic districts (Table 5.3).

Table 5.3 Functional Aspects of Metro and Its Impact

Criteria	Station	Very Low	Low	Average	High	Very High	Total
Ease of Movement (Home–Work)	Tajrish	2%	5%	17%	51%	25%	100%
	Mirdamad	2%	3%	17%	58%	20%	100%
	Khayam	2%	3%	12%	55%	28%	100%
Ease of Access to Facilities	Tajrish	3%	5%	25%	40%	27%	100%
	Mirdamad	7%	3%	33%	37%	20%	100%
	Khayam	5%	3%	35%	32%	25%	100%
Vitality and Daily Efficiency	Tajrish	20%	10%	28%	28%	14%	100%
	Mirdamad	18%	12%	45%	22%	3%	100%
	Khayam	15%	8%	40%	25%	12%	100%

Regarding commute duration, the majority of users (46%) reported travel times exceeding 30 minutes. Only 25% stated that their commute takes less than 30 minutes, and 29% reported exactly 30 minutes. The highest percentage of longer travel times was found among users of Tajrish Station (50%), due to its terminal location at the end of the metro line. In contrast, Khayam Station users reported the shortest commute, with 27% reaching work in under 30 minutes. Also, 50% of users switch lines once during their commute, while 36% change lines twice, highlighting the role of line connectivity in total travel time (Table 5.4).

Table 5.4 Travel Time Between Home and Workplace by Metro

Station	≤10 min	20 min	30 min	45 min	60 min	>60 min	Total
Tajrish	2%	23%	25%	15%	25%	10%	100%
Mirdamad	7%	18%	33%	23%	8%	10%	100%
Khayam	7%	20%	28%	27%	8%	10%	100%
Total	5%	20%	29%	22%	14%	10%	100%

In terms of economic efficiency, 43% of respondents across all stations indicated that metro use has significantly reduced their commuting costs, while 22% claimed an increase in expenses. Fewer than 12% saw no substantial change. Cost benefits were slightly more pronounced for users at Tajrish and Mirdamad (70%) compared to Khayam (68%), likely due to longer distances to central services from the northern districts. In terms of fare expenditure, 43% of users spend between 10,000 and 20,000 Rials, 26% spend between 20,000 and 30,000 Rials, and 18% spend less than 10,000 Rials per trip (Table 5.5).

Table 5.5 Metro Fare vs. Personal Vehicle Costs

Station	Much Lower	Somewhat Lower	No Change	Somewhat Higher	Total
Tajrish	43%	27%	12%	18%	100%
Mirdamad	43%	27%	7%	23%	100%
Khayam	43%	25%	9%	23%	100%
Total	43%	26%	9%	22%	100%

Regarding accessibility by walking, 40% of metro users reach the station on foot. A significant majority (68%) reported walking durations of 5 to 15 minutes, aligning with Transit-Oriented Development (TOD) standards. 22% indicated walking times exceeding 20 minutes. Notably, Khayam Station provides the most walkable conditions, with 55% of respondents reporting a walking time of 5–10 minutes, followed by Mirdamad (53%) and Tajrish (43%) as presented in Table 5.6.

Table 5.6 Walking Time to Metro Station from Home or Workplace

Station	≤5 min	5–10 min	10–15 min	15–20 min	>20 min	Total
Tajrish	13%	20%	23%	19%	25%	100%
Mirdamad	18%	30%	23%	7%	22%	100%
Khayam	18%	35%	20%	9%	18%	100%
Total	17%	28%	22%	11%	22%	100%

4.3. Statistical Analysis

This section presents the estimation results of socio-economic and functional factors influencing metro usage for commuting between home and workplace, based on a Mixed Logit Model.

Socio-Economic Variables - The sign of the driver's license variable aligns with expectations: individuals without a driver's license are more likely to prefer metro use. Despite most respondents owning at least one vehicle, many opt for the metro to avoid traffic congestion and reduce vehicle depreciation. Although income is not statistically significant, its coefficient sign matches theoretical expectations. Higher-income individuals appear more aware of the environmental benefits of metro use (Table 5.7)

Table 5.7 Estimation Results of Socio-Economic Variables Affecting Metro Usage (Mixed Logit Model)

Variable	Coefficient	Standard Deviation	Z-Statistic	P-Value
Constant (C)	-2.9140	1.5381	-1.89	0.058
Gender	0.7114	0.4103	1.73	0.083
Age	0.1569	0.0503	3.12	0.002
Income	0.0004	0.0004	0.96	0.336
Education	-0.0401	0.4476	-0.92	0.355
Driver's License	-0.4140	0.4476	-0.92	0.355
Car Ownership	0.0399	0.4673	0.09	0.932

Age has a positive and statistically significant effect on metro usage (p = 0.002), suggesting that older individuals are more inclined to use the metro. Gender demonstrates a marginally significant effect (p = 0.083), implying potential gender-based variation in metro use. Other variables such as income, education, driver's license, and car ownership do not significantly influence metro usage in this model (Table 5,8).

Table 5.8 Marginal Effects of Socio-Economic Variables on Metro Usage in Tehran (Mixed Logit Model)

Variable	Coefficient	Standard Deviation	Z-Statistic	P-Value
Gender	0.1088	0.0630	1.73	0.084
Age	0.0240	0.0059	4.01	0.000
Income	0.00006	0.00007	0.96	0.339
Education	-0.0061	0.0095	-0.64	0.521
Driver's License	-0.0633	0.0693	-0.91	0.361
Car Ownership	0.0061	0.0715	0.09	0.932

Age has a statistically significant positive effect (p < 0.001), indicating older individuals are more likely to use the metro. Gender shows a marginally significant effect (p = 0.084), suggesting possible gender-based differences in metro usage patterns. Other socio-economic variables such as income, education, driver's license, and car ownership do not show statistically significant effects (Table 5.9).

Table 5.9 Estimation Results for Functional Variables Influencing Metro Travel Mode Choice (Mixed Logit Model)

Variable	Coefficient	Standard Deviation	Z-Statistic	P-Value
Constant (C)	-0.0244	0.5667	-0.04	0.966
Metro travel time	0.0202	0.0104	1.94	0.053
Comparison of metro travel cost vs. personal vehicle	-0.0643	0.3764	-0.17	0.864
Metro's impact on vitality and productivity	0.7890	0.3869	2.04	0.041
Metro's impact on ease of access to city's main facilities	0.1326	0.4020	0.33	0.741
Metro's impact on ease of movement between home and workplace	0.4862	0.4883	1.00	0.319

The variable "Metro's impact on vitality and productivity" is statistically significant at the 5% level (p = 0.041), indicating a strong influence on the decision to use the metro. "Metro travel time" is marginally significant (p = 0.053), suggesting a possible effect that warrants further investigation. Other functional variables show positive but statistically insignificant effects on travel mode choice.

4.3.1 Functional Variables

Tables 5.8 and 5.9 report results for functional characteristics related to metro travel mode choice.
The metro travel time variable has a positive and statistically significant effect (p = 0.053), indicating that longer metro travel times (implying greater coverage) increase the probability of metro usage.

The effectiveness of metro in enhancing vitality and productivity also significantly increases the likelihood of metro use (p = 0.041). This suggests that commuters who feel more productive and energetic while traveling by metro are more inclined to choose it consistently.

The variable comparing metro travel cost with personal vehicle cost is not statistically significant but has a negative coefficient, consistent with expectations: increased metro costs relative to personal vehicle costs reduce metro usage probability. Similarly, variables representing the effectiveness of metro in easing access to city facilities and facilitating movement between home and workplace are not statistically significant but exhibit positive signs aligned with theoretical expectations (Table 5.10).

Table 5.10 Marginal Effects of Functional Variables on Metro Travel Mode Choice (Mixed Logit Model)

Variable	Coefficient	Standard Deviation	Z-Statistic	P-Value
Metro travel time	0.0036	0.0018	1.97	0.048
Comparison of metro travel cost vs. personal vehicle	-0.0116	0.0681	-0.17	0.864
Metro's impact on vitality and productivity	0.1429	0.0690	2.07	0.038
Metro's impact on ease of access to city's main facilities	0.0240	0.0727	0.33	0.741
Metro's impact on ease of movement between home and workplace	0.0880	0.0879	1.00	0.317

The variables metro travel time and metro's effect on vitality/productivity are statistically significant at the 5% level ($p < 0.05$), suggesting a meaningful impact on mode choice behavior. The other variables, while aligned with theoretical expectations, are not statistically significant.

4.3.2 Summary of Significant Effects

Among significant variables, the effectiveness of metro on vitality and productivity has the highest marginal effect (14.29%) on metro usage probability, highlighting its critical role in influencing mode choice. Gender is the next most influential factor (10.88%), followed by age (2.4%) and metro travel time (0.36%). These results underscore the importance of both individual characteristics and perceived benefits of metro travel in shaping commuters' transport mode decisions.

5. DISCUSSION

The descriptive analysis reveals that most respondents at all three stations predominantly use the metro for commuting between home and workplace. The Mixed

Logit Model further helps identify which variables significantly influence the willingness to use the metro.

Previous studies have established a significant relationship between sustainable travel patterns and gender (Polk, 2003; Manaugh *et al.,* 2010; Nor *et al.,* 2013). For example, gender influences the preference for private vehicles among students. The literature shows that females tend to undertake more trips than males in many countries and generally demonstrate greater willingness to use public transportation due to typically shorter daily trips (Pourhashem *et al.,* 2019). This study confirms a significant association between metro use and gender; interestingly, descriptive data suggest that males use public transport more than females.

Age is another important factor influencing transport demand. As noted by Hammadou and Mahieux (2014), younger individuals tend to use public transport more, often due to lack of a driver's license. Pourhashem *et al.* (2019) also found significant travel pattern differences among female subgroups, noting that older women tend to drive less and cease driving earlier than older men. Our findings align with these studies, showing a positive and significant correlation between metro use and age ($p = 0.009$). The 18 to 35 age group, characterized by high employment and mobility between home and work, exhibits the highest propensity to use public transport. Conversely, car driving is predominant among older age groups (Hammadou & Mahieux, 2014).

Regarding income, Tehran's socio-economic distribution shows higher income levels from south to north. Nor *et al.,* (2013) found significant links between willingness to switch to public transport and monthly income. Lower-income groups tend to be more sensitive to public transport costs than car expenses (Hammadou & Mahieux, 2014). Education also plays a role in commute behavior; Manaugh *et al.,* (2010) found that higher education correlates with longer commutes using sustainable modes. Rahman (2020) noted that preference for walking or rickshaw declines with increased education. However, this study finds no significant relationship between education level and metro use, though the negative coefficient aligns with theoretical expectations.

Car ownership and driver's license status impact travel mode choice. According to Hensher (1998) and Meyer (1999), increasing solo car travel costs reduces car's attractiveness. Similarly, Hammadou and Mahieux (2014) reported that car purchase costs limit car ownership among low-income groups, making them more captive to public transport.

In Iran's current economic context with high inflation and rising car prices, low-income individuals often cannot afford cars. Conversely, lack of parking space can discourage car use. Descriptive analysis shows nearly half of respondents lack dedicated parking, which likely encourages public transport use. Although most respondents reported reduced personal vehicle use due to metro availability, no significant statistical relationship was found between car ownership and travel pattern choice, despite coefficient signs supporting expectations.

Regarding driver's license possession, only a minority reported using the metro due to not having a license, and no significant statistical relationship was observed between license status and metro use. This contradicts some previous findings, but the variable's coefficient sign aligns with expectations.

Among functional factors influencing metro satisfaction, only metro travel time and the effectiveness of metro in enhancing vitality and productivity show significant relationships with travel mode choice. Conversely, metro travel costs (compared to personal vehicles), ease of access to city facilities, and ease of movement between home and workplace do not have significant statistical effects, despite over half of respondents citing their importance.

Time saving emerges as the most critical factor influencing metro use. Hammadou and Mahieux (2014) found that travel time negatively and significantly affects transport mode demand. Rahman et al. (2020) and Nasrin (2017) similarly highlight travel time as a key determinant in mode choice and travel behavior. Feudo (2014) noted that faster transport systems increase average travel distances, suggesting willingness to use the metro increases with longer home-to-work distances due to time savings. Nearly half of respondents emphasized time saving's importance, especially given the high traffic density and congestion around stations. Mixed Logit Model results confirm a positive significant link between travel time and metro use ($p = 0.048$).

Travel cost reduction is often viewed as a motivating factor for public transport use (Heres *et al.,* 2013; Hammadou & Mahieux, 2014). Most respondents agreed that metro reduces commuting costs compared to private vehicles. However, no significant statistical relationship was found between travel cost and metro use, though the negative coefficient indicates increased metro cost reduces its use probability, consistent with expectations.

Accessibility to services and ease of movement between home and workplace are often linked to travel mode choices (Nakshi *et al.,* 2020; Benenson *et al.,* 2011). Descriptive analysis suggests these factors influence metro use, but statistical tests do not confirm significance. Nonetheless, coefficient signs align with expectations, indicating potential relevance.

6. CONCLUSIONS

The study's findings align with prior research demonstrating the impact of urban form and socio-economic characteristics on daily travel production and mode choice. Beyond individual attributes, travel patterns are shaped by personal preferences and behavioral tendencies. Recognizing these factors is vital for policymakers aiming to foster sustainable travel patterns.

Improving public transportation systems can encourage greater metro use. However, urban transportation planning must extend beyond physical infrastructure to encompass residents' lifestyle, preferences, and desires. Functional policies that integrate

these human factors alongside urban design can effectively influence travel behavior.

Despite Tehran's relatively developed transport infrastructure, challenges remain in ensuring easy access and sustainable commuting between home and workplace. Enhancing the quantity and quality of transport services, including public transit and active transport facilities, supports the development of sustainable mobility aligned with transit-oriented development (TOD) principles.

Traffic restriction policies targeting private car use have reduced car trips, but their effectiveness is limited without complementary measures such as expanding and improving public transport, creating pedestrian- and bicycle-friendly environments, and optimizing land use diversity.

Provision of secure parking near metro stations encourages park-and-ride behavior. Upgrading pedestrian infrastructure and bike lanes enhances last-mile connectivity and promotes clean transportation, reducing car dependency and pollution.

Service capacity improvements, including connecting modes like buses and taxis, social and cultural amenities, and improved station access are also necessary. Land use strategies focusing on compressing urban fabric around metro stations with mixed-use development and decentralizing services reduce trip lengths and distribute travel demand.

Future research should analyze interdependence among travel behavior factors to identify their relative importance. Investigations into government policies and travel desirability are recommended. Innovative approaches such as social marketing may institutionalize sustainable travel behaviors and inform urban mobility planning.

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