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Original Article

AN EVALUATION STUDY ON IMMIGRANTS' TRANSPORT SYSTEM ADAPTATION BEHAVIOUR: TURKEY EXAMPLE

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Highlights:

- research defines the immigrants' transport integration;
- high transport costs, unclear traffic signals, and language barriers are main obstacles;
- communication and language issues strongly correlate with public transport utilization;
- the question of "immigrants' transport system adaptation problems" answered statistically;
- study shows that age is the most significant factor influencing immigrants' adaptation.

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Abstract. Global migration patterns have led to significant population shifts, particularly in regions such as Turkey, which has experienced a substantial influx of immigrants due to political crises, economic instability, and armed conflicts. This study examines the adaptation behaviour of immigrants to Turkey's transport system, identifying key challenges, expectations, and integration patterns. Using survey data from immigrants in Turkey, the study explores the role of demographic factors, prior transport experiences, and socio-economic conditions in shaping mobility choices. The findings indicate that while many aspects of Turkey's transport system are familiar to immigrants, significant barriers such as high travel costs, unclear traffic signage, and language-related difficulties hinder complete adaptation. Younger, higher-educated immigrants and those from culturally similar backgrounds demonstrate a faster integration process, whereas older immigrants and those with limited educational backgrounds face more significant obstacles. Statistical analyses, including multiple linear regression and decision tree classifier, reveal that age is the most significant predictor of long-term transport adaptation. Additionally, the study highlights that as the duration of stay increases, immigrants exhibit a higher reliance on public transportation, with ownership of private vehicles gradually rising among long-term residents. The research underscores the need for policy interventions, such as reducing transport costs, improving multilingual signage, and offering integration programs to enhance immigrant mobility. These insights provide valuable guidance for policymakers, urban planners, and transport authorities striving to develop more inclusive and efficient transport systems.

Keywords: immigrants, transportation, adaptation, decision tree classifier, survey.

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Notations

Abbreviations:

DTC – decision tree classifier;
KMO – Kaiser–Meyer–Olkin;
LOESS – locally estimated scatterplot smoothing;
PCA – principal component analysis;
PDT – pruned decision tree.

Variables:

y – response variable;
α – model intercept;
ϵ – error term (residual);
γ_n – independent variables.

1. Introduction

Several factors have contributed to increased international migration in recent years. These include armed conflict, the pursuit of greater political and economic freedom, the emergence of new diseases, the desire for improved living standards, and the search for more favourable conditions. In addition, the movement of people between countries and even continents has been driven by various political, economic, and social factors. The concept of migration has existed since the earliest recorded history. Mass migration can potentially alter the fate of geographies, the cultures of the people residing in the region, the identities of the immigrants themselves, and the political balances of countries. The significant influx of individuals into Europe between 350 and 800 AD, designated as the migration of the tribes, inaugurated a new epoch. The concept of migration gives rise to the terms "refugee" and "immigrant". These terms, often used interchangeably, refer to different situations and do not have the same meaning. In accordance with Article 1A(2) of the United Nations Convention Relating to the Status of Refugees, a "refugee" is defined as an individual who has a well-founded fear of being persecuted for reasons related to their race, religion, nationality, membership in a particular social group, or political opinion (Nygh 2000). A refugee is defined as an individual who, due to a well-founded fear of persecution on the grounds of race, religion, nationality, membership of a particular social group, or political opinion, is outside the country of their nationality and is unwilling to seek the protection of that country. Conversely, the term "immigrant" cannot be defined by a universal international definition. The United Nations defines an immigrant as someone who resides in a foreign country for one year, irrespective of the underlying motives, whether voluntary or involuntary, the migration routes pursued, and whether the migration is regular or irregular.

Immigrants relocate within a country for various reasons, including shopping, pursuing educational opportunities, receiving medical care, and engaging in social activities. Some will undertake the journey by private vehicle, while others will utilize public transport. Immigrants may find themselves confronted with a disparate transport culture and infrastructure. The transport behaviour of immigrants may vary according to their socio-economic status and the social culture in which they are embedded. When immigrants commence residence in a novel country and city, they may encounter challenges due to a lack of familiarity with local traffic patterns and public transportation systems. In particular, language barriers and disparate transport practices can extend the adaptation period. The phenomenon of contemporary migration, predominantly from less developed to more developed countries, presents a significant challenge for individuals from less developed countries with limited education, who often need help adapting to the existing system. Such circumstances can give rise to several disruptions and issues for immigrants and other users alike. In addition to educational attainment, income status can also impede the process of adaptation. Those with low incomes may need help paying the fare for public transport, which may result in their continued use of their preferred mode of transport, such as cycling or walking. Conversely, higher-income people may be more likely to utilise private vehicles instead of public transport. It is incumbent upon the relevant authorities to facilitate the adaptation of individuals to social life to eliminate the potential for disruption and establish more effective systems. Transport systems must be made more accessible and easier to use to eliminate the transport-related issues that immigrants face. Such measures would also be beneficial for disabled and older adults, as well as immigrants. Furthermore, various informational initiatives must be implemented to guarantee that immigrants optimally utilize the public transportation infrastructure. In addition to training and harmonization activities, the effective use of multilingualism and intelligent applications in information systems represents a promising approach to eliminating disruptions.

Turkey has witnessed a considerable increase in refugees and immigrants over the past 2 decades. As indicated by the data provided by the Republic of Turkey Ministry of Interior Directorate of Migration Management (T. C. İçişleri Bakanlığı – Göç İdaresi Başkanlığı 2024), the country currently hosts approximately 4 million foreign nationals, including over 3 million Syrians under temporary protection and more than a million individuals with residence permits. Given its geopolitical position, Turkey represents a key transit point for numerous Asian and European countries seeking to reach Europe via illicit means. Additionally, Turkey has many European guests, mainly attributable to its favourable tourism opportunities and climate. As a consequence of the recent armed conflict between Russia and Ukraine, a considerable number of both Russian and Ukrainian citizens have also migrated to Turkey. Furthermore, it is a common destination for immigrants from the Turkestan region, mainly due to the diverse employment opportunities and high-quality education system. Moreover, the spouses and families of Turkish citizens who marry individuals from different nationalities may also choose to migrate to Turkey. Individuals from disparate national and ethnic backgrounds coexist with Turks in the same spaces, residential buildings, and educational institutions. Furthermore, the same urban mobility systems are utilized. While it is acknowledged that these cultural and social divergences can be perceived as an asset, they can also give rise to numerous challenges for transportation systems.

The success of transport planning studies is contingent upon accurately identifying the prevailing circumstances, concerns, and expectations. In cases where precise definitions cannot be established, implementing improvements may only sometimes lead to optimal results. The success of transport planning is of great importance in constructing a more user-friendly, safer, and more sustainable transport system. This study examines the situation of immigrants and refugees in the transport systems of Turkey,

which receives a significant number of immigrants and refugees from diverse geographical origins. A detailed study of the reasons for the presence of immigrants and refugees of different ages, genders, and nationalities in Turkey, the status of driving license holders, transport preferences, and transport difficulties were carried out through a field survey. Participants were also asked to compare road quality, pedestrian and driver behaviour, public transport, and road safety in their respective countries and Turkey. This approach was taken to analyse the potential barriers that immigrants and refugees may encounter when attempting to adapt to the transport systems in Turkey. The study also examined the difficulties faced by immigrants and refugees living in Turkey concerning transport systems and their use. The research aims to determine the extent to which immigrants use existing systems and to identify the problems observed, both qualitatively and quantitatively.

2. Background

Today, many immigrants in Turkey are classified under several categories, including asylum seekers, refugees, immigrants, and those under protection (Çelik 2020). Immigrants who have left their country of origin for various reasons face several challenges in the countries to which they migrate. At the same time, the country of immigration also faces disruptions that immigrants may cause. While it is possible to facilitate immigrants' integration into the existing state order of the countries to which they migrate quickly through legislative measures, their integration into social life may occur later (Adıgüzel 2016). The rules and laws to which immigrants are subject are set out in the relevant legislation. Immigrants are entitled to fundamental rights and obligations, including work permits and the right to reside within the country's borders, provided they comply with the relevant legislation. However, the process of acculturation is more complex and protracted for immigrants. The method of acculturation involves several elements, including the acquisition of a new language, the understanding of the cultural and traditional patterns of the host country, the formation of social relationships, and the acceptance of the individual as a member of the wider society. In particular, significant linguistic and cultural differences can be a substantial barrier to the social integration of immigrants, resulting in a lack of communication and social ties with the local population. Many actors may be involved in immigrants' adaptation to social life, and several disturbances may occur. In addition, the reasons why migrants migrate can also lead to significant differences in their adaptation to social life (Aydin, Topal 2016, 2019; Gonzalez-Feliu *et al.* 2018; Shelest-Szumilas, Wozniak 2024). The ability of immigrants to maintain their daily lives in the local community, despite cultural and linguistic differences, can be guaranteed through the collective efforts of all stakeholders (Adıgüzel 2023). It is imperative that stakeholders in critical sectors, including education, health, and social services, develop unified solutions to address the needs of immigrants to accelerate the harmonization process. To this end, it is essential to establish a solid framework for communication and cooperation between local authorities, non-governmental organizations, and state institutions. However, recent studies on migration issues have employed a more critical language (Favell 2022). To prevent the formation of socially isolated immigrant groups for various reasons, it is essential to work with all relevant stakeholders to ensure immigrants' access to crucial public services, particularly education and health care, and to promote social cohesion among immigrants. (Buran 2024). Currently, local authorities bear a significant responsibility for ensuring the adaptation of immigrants to social and urban life (Babaoğlu, Kocaoğlu 2017). It is within the power of municipalities to facilitate the mobility and social integration of immigrants by providing transport and social services that meet their needs. In addition, local authorities can facilitate the integration of immigrants into the local community by providing language training and cultural awareness programs. To design an effective program for the adaptation of immigrants, it is of the utmost importance to accurately identify the problems that immigrants and their host countries face due to migration. This situation provides fertile ground for scientific research. The following topics can be considered: health, education, and social life. A considerable amount of research has been done on integrating immigrants into health and education systems, examining the differences between them and the challenges they face, particularly in health and education.

Immigrants may have biological differences from people in their countries of origin due to genetic factors. They may also be susceptible to infectious diseases due to a lack of vaccination or diagnosis. A substantial body of research on the relationship between migration and health exists. As shown by Hemminki (2014), immigrants from Africa have a higher prevalence of hepatitis B and hepatitis C viruses compared to the European countries to which they migrate. In addition, immigrants may contribute to the resurgence of malaria in Europe. Khyatti *et al.* (2014) highlighted that those infectious diseases carried by immigrants include new and deadly pathogens. It was also noted that immigrant communities are a vulnerable group contributing to the spread of disease. It was also pointed out that continuous surveillance is needed because of the potential impact of the influx of immigrants on changing patterns of infectious diseases in Europe. Another major challenge that immigrants face upon arrival in their destination countries is access to education. In addition to cultural differences and disparities in education systems, immigrants face a variety of challenges, including armed conflict, food insecurity, and economic hardship, which often result in insufficient attention to education or limited access to educational opportunities. Immigrants who lack the necessary education level and are of an advanced age have difficulties adapting to the social milieu of the countries to which they migrate. For example, the idea that immigrants will eventually become per-

manent residents of Turkey is gaining traction. In light of these considerations, the education of immigrant children is becoming an increasingly important issue (Sezgin, Yolcu 2016). The education of immigrant children is paramount for the children's and their families' social integration. Including immigrant children in the education system has been shown to facilitate their academic achievement and social integration. An effective education enables children to make significant progress in terms of language acquisition and cultural understanding, facilitating their integration into the local community. Effective education for immigrants facilitates their integration into society (Ereş 2015). Language differences are also a significant factor. In their study, Gibson & Carrasco (2009) concluded that immigrant pupils experience feelings of exclusion when using their mother tongue and that school ideologies result in immigrant pupils feeling silenced and alienated, despite the school's egalitarian approach. Furthermore, they emphasized that the misguided implementation of adaptation processes, ostensibly in the name of adaptation studies, has the unintended consequence of alienating immigrant pupils from their peers and prolonging this process. However, they emphasize that the effectiveness of educational programs is enhanced by embracing multilingualism and diversity rather than attempting to integrate immigrant pupils into the existing system.

In addition, researchers have conducted considerable research on immigrants' social lives and mobility patterns. Immigrants are constantly on the move to maintain their social lives, including accessing health services, pursuing educational opportunities, or engaging in commercial activities. As they move, they interact with other people and vehicles. Conversely, discrepancies may arise between immigrants and the local population. New immigrants from abroad use public transport more than existing residents. As a result, the influx of a new wave of immigrants has led to a notable increase in demand for public transport (Chakrabarti, Painter 2019). The demographic characteristics of individuals, including age, income, gender, and educational attainment, have been identified as influencing travel behaviour (Polzin *et al.* 2000; Rosenbloom, Fielding 1998). The transport preferences of immigrants vary according to the length of time they have lived in a particular place. Furthermore, differentiation in the origins of individuals migrating to a country over time and changes in the distribution of countries over time can be identified as additional factors contributing to the observed differentiation in transport preferences. In addition, income levels and the structure of the region of residence may serve as determinants of immigrants' transport preferences (Hanna 2021). As Blumenberg and Evans (2010) note, immigration to the US leads to changes in the population and structure of the country. The immigrant population is concentrated in certain regions. Regional disparities accompany this demographic shift. There is a paucity of academic research examining the relationship between migration and travel. The results of the studies indicate a decrease in the use of public transport by immigrants compared to previous years. Demand for public transport depends on the time and monetary cost of driving. Immigrants are more likely to have lower incomes than the native population and face greater difficulties in purchasing private vehicles (Chapman, Bernstein 2003). Car ownership rates vary considerably between countries (Kenworthy, Laube 2002). Differences in car ownership rates also suggest differences in driving habits. A significant proportion of immigrants to the US come from countries where the prevalence of private car ownership is relatively low compared to the US. However, once they have achieved sufficient economic stability, many immigrants purchase and use personal vehicles, citing increased speed and convenience (Blumenberg, Smart 2011). In a separate study, Waslin (2013) found that minor traffic offenses can result in the arrest and deportation of immigrants, highlighting the potential for traffic offenses to become avenues for immigration enforcement. This situation can make immigrants reluctant to drive. As a result, immigrants are unable to engage in social activities, which hinders the adaptation process. Another mode of transport favoured by immigrants is the bicycle, which is easily accessible and a more economical solution. Smart (2010) found that immigrants use bicycles more than natives and that immigrants' preference for bicycles varies according to their nationality. In line with the findings of previous studies, it can be concluded that demographic and socio-economic factors are the main determinants of immigrants' preferences for different modes of transport, including public transport, private cars, and bicycles.

A common focus of studies examining the role of immigrants in transport systems is the extent to which immigrants use different modes of transport. However, transport planning studies need to consider the integration of immigrants into the system, taking into account the impact of immigrants on transport systems, their usage habits, and the difficulties they encounter. At this point, it is imperative to identify immigrants' challenges, the underlying factors that influence their transport preferences, and historical transport habits. An awareness informed the research of the shortcomings of the existing literature on the subject. While there are some generalizations, particularly regarding usage preferences, issues of expectations and satisfaction are typically not explored. In line with the stated objectives of the study, the aim is to identify the current situation, expectations, and problems from the immigrant perspective by asking comprehensive questions of immigrants. At the same time, by examining the system from the immigrant's point of view, the aim is to identify any potential disruptions that immigrants may cause to the maintenance of the ideal social order. In this way, the study attempts to address the lack of research on Turkey and immigrant-oriented transport issues in the existing literature, to provide a reference point for similar studies.

3. Material and methods

3.1. Data description

Antalya city, which has the most significant number of immigrants and the most incredible diversity of origin in Turkey, was selected as the pilot site for the study (Figure 1). A survey was conducted with randomly selected 200 immigrants from the target population (n = 200) who agreed to participate the study.

A questionnaire was administered to the participants in person. The study collected data on the main demographic characteristics of the immigrants, including age, gender, level of education, nationality, and marital status. Participants were also asked about the duration and reasons for their permanent residence to understand their motivations for staying in Turkey and their profiles as immigrants. Other questions were asked to determine the participants' driving license and car ownership status and their views on various transport issues, including pedestrian safety and public transport infrastructure. To determine the factors influencing the use of public transport by immigrants in Turkey, questions were asked about the purpose and frequency of use of public transport and the problems encountered from the participants' perspective. At this point, the aim is to identify the problems caused by language differences and communication accurately.

Figure 1. The location of Antalya city in Turkey

3.2. Participant statistics

In the study, a statistical analysis was conducted to define the characteristic properties of immigrants, as given in Table 1. Table 1 shows the number of respondents in different countries and their corresponding percentages [%] of the total respondents. The major countries presented were Russia, Ukraine, Turkmenistan, and Syria, indicating a broadly assorted sample from these areas. This total percentage enables one to see how much each country contributes to the total survey, bringing out the primary respondents' figures.

The statistics in Table 1 clearly show immigrants in Turkey because of unrest, war, or administrative problems in their countries. The statistics obtained in the study show that in Antalya, Russians (37.5%) and Ukrainians (12%) are in the 1st 2 places. This situation shows that Turkey has received significant immigration from these 2 countries due to the Russian–Ukrainian war. Similarly, Turkmenistan, which is 3rd, shows that many Turkmen have emigrated due to their dissatisfaction with the administration and

Table 1. Nationality representation of respondents in the sample population

No	Country	Number	Percentage [%]	Cumulative percentage [%]
1	Russia	75	37.5	37.5
2	Ukraine	24	12.0	49.5
3	Turkmenistan	20	10.0	59.5
4	Syria	16	8.0	67.5
5	Azerbaijan	12	6.0	73.5
6	Iran	11	5.5	79.0
7	Belarus	9	4.5	83.5
8	Palestine	8	4.0	87.5
9	Iraq	7	3.5	91.0
10	Kazakhstan	4	2.0	93.0
11	Jordan	3	1.5	94.5
12	Moldova	3	1.5	96.0
13	Georgia	2	1.0	97.0
14	African countries	2	1.0	98.0
15	Uzbekistan	2	1.0	99.0
16	Kyrgyzstan	1	0.5	99.5
17	Lebanon	1	0.5	100.0

Table 2. Characteristics properties of the immigrants

Parameter	Definition	Immigrants [%]		
		≤1 year	1< year <5	≥5 years
Age	18...24	11.1	3.4	1.6
	25...49	72.2	90.8	84.1
	50...56	16.7	5.9	9.2
	57+	0.0	0.0	4.7
	μ	35.9	35.8	38.8
	σ	10.6	7.8	9.3
Gender	female	83.3	70.6	66.7
	male	16.7	29.4	33.3
Education level	primary	0.0	0.0	0.0
	high school	16.7	14.3	14.3
	associate	16.7	21.	12.7
	BSc	50.0	55.5	55.6
	MSc	16.7	8.4	17.5
	PhD	0.0	0.8	0.0
Residence status	owner	5.6	10.9	38.1
	tenant	83.3	72.3	47.6
	purchased	11.1	16.8	14.3
Marital status	single	66.7	57.1	41.3
	married	33.3	42.9	58.7
Children	no children	61.1	64.7	52.4
	have children	38.9	35.3	47.6

Note: μ shows the mean value; σ shows the standard deviation.

economic situation. In 4th place are Syrians fleeing the civil war in their country. According to the results in Table 1, the main problem in migration to Turkey is the chaos in the countries of the individuals.

Information on the demographic and characteristic features of the migrants was analysed as given in Figure 2. Figure 2 presents a demographic overview of the surveyed immigrant population, offering insights into the profile of this demographic group. The age distribution indicates that most immigrants are within the 30...40 age range, which suggests that they are predominantly in their working years. Conversely, there is a discrepancy of several years between the age distributions of men and women in the 30...40 age interval. This suggests that men are more likely than women to marry at an earlier age within this community. Regarding ethnicity, it is often the case that individuals consider their own religion or cultural group rather than their nationality. Sometimes, individuals may have ambivalent feelings and thus may have mixed reactions until they meet someone from that particular country. The sequencing analysis indicated that Russia was the most common country of origin, followed by Turkmenistan and Azerbaijan. Additionally, the level of education demonstrated that a significant proportion of respondents had attained primary education. The findings mentioned above provide an in-depth analysis of the demographic and educational background of the migrants who participated in this study.

In the study, a descriptive analysis was also conducted to determine the social and characteristic properties of the immigrants. Obtained results are given in Table 2.

Table 2 shows the characteristic profile of foreign nationals in Turkey, grouped according to their length of stay. The categories are ≤1 year, 1 year <5 years, and ≥5 years. The research encompasses a range of variables, including age, gender, educational level, residential status, marital status, children, driving license possession or otherwise, means of transport, and perceptions of private vehicle ownership about public transport services, infrastructure, road quality and condition, road safety, and traffic control and pedestrian safety measures. This information highlights clear trends for different lengths of stay, emphasizing disparities in age composition, literacy rates, and modes of transport, including residents over time. When these factors were considered collectively, a notable trend emerged. Older immigration groups exhibited a higher prevalence of vehicle ownership and demonstrated a greater emphasis on driving safety compared to their countries of origin.

3.3. Transportation habits and activities

It is well known that public transport systems, traffic mobility, attitudes, and behaviour of passengers and drivers in traffic can vary greatly from one country to another. The most important factors are traffic culture, driver training, penalties, and the individual's tendency to obey the rules.

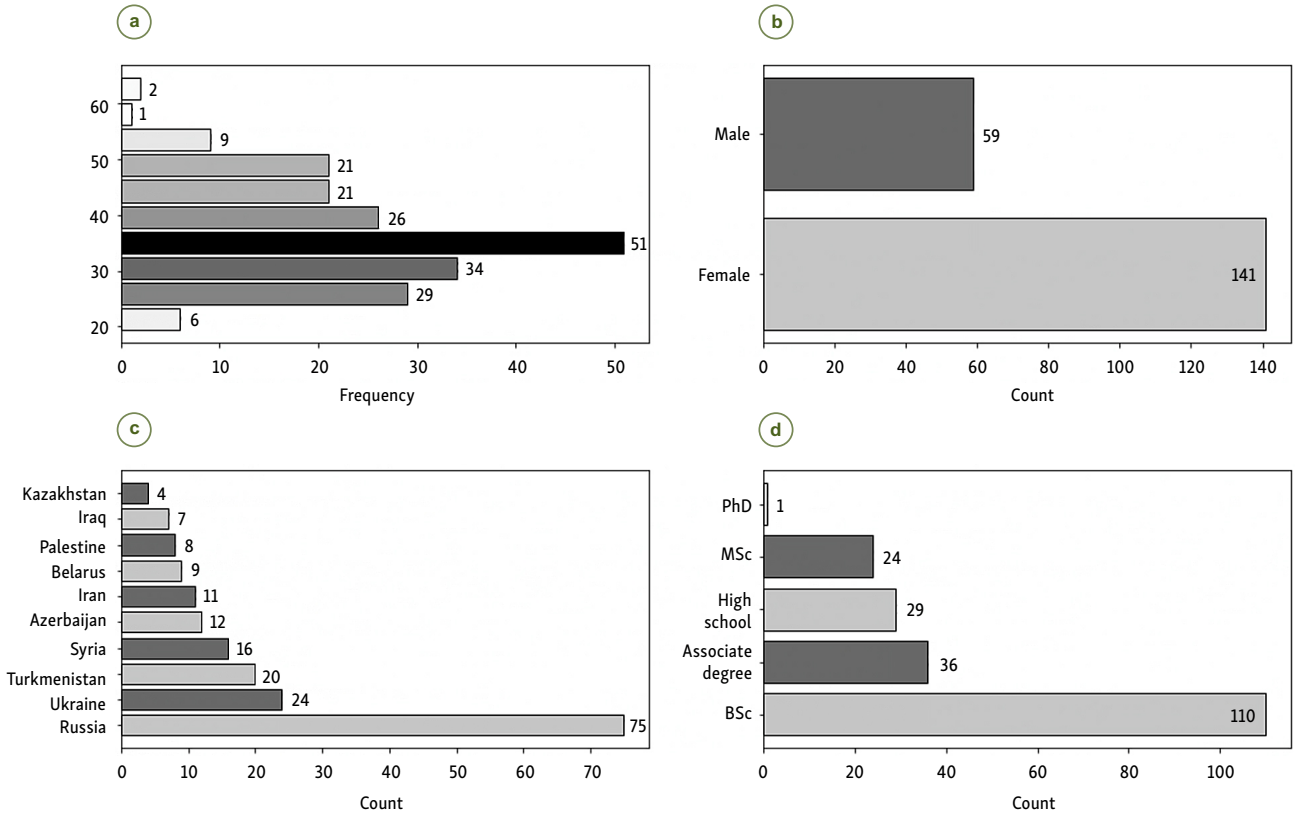

Figure 2. Demographic overview distributions:
(a) – age; (b) – gender; (c) – top 10 nationalities; (d) – education level of the surveyed immigrant population

For this reason, when people move to different countries, they may not be able to adapt quickly to the traffic system of that country. If the language problem is added to all these situations, getting used to the new system can be even longer. For this reason, this study examined the current transport habits and activities of the participants living in Turkey, one of the countries with the largest immigrant population in the world. For this aim, 1st of all, the transport activities and characteristics of the migrants were obtained as shown in Table 3.

An analysis of Table 3 shows that most participants have been using public transport for more than 5 years (77.8%). When analysing car ownership, it can be seen that the majority do not own a car. When analysing the ownership of bicycles, it can be seen that they have been used for less than a year (22.2%). Again, the statistics show that those with a good income level own more than one vehicle. When migrants compared the transport systems, traffic characteristics, and road conditions in their countries of origin and Turkey, they stated that the quality of public transport systems was almost similar to that in their countries of origin (66.7%, 60.5%, and 63.5%, respectively). The situation was quite different for the quality of roads in cities. Immigrants indicated that the quality of roads in their countries of origin was better than in Turkey. It was concluded that driver and pedestrian characteristics and road safety features were similar to those in their home countries and public transport. According to the participants' answers, it can be said that other characteristics than road quality are similar.

From the analyses, the immigrants' transportation habits statistics were obtained as shown in Figure 3. The figure shows various elements of transportation activities. Private vehicles top the list of means of transport, followed by public transport, while cyclists, scooter users, and pedestrians use bicycles the least. As far as owning vehicles is concerned, quite a few respondents do not possess any car. However, many of those who own cars mostly own them instead of owning physical motorcycles or bicycles. The part of Figure 3 labelled "Transportation options used" emphasizes ownership of private vehicles as the most relied upon mode of transportation, while rental cars and public transport are also important. Commuting to work and shopping are the leading reasons for traveling, as demonstrated in the purpose of transportation graph, followed by socializing activities, in which fewer respondents justify their movement by school going or seeking children's attention.

Figure 4 provides an overview of the transport difficulties in Turkey and shows that the most significant problems are the high cost of moving around the country, the lack of clear signage and directions, and issues with cleanliness. In order to improve the overall performance of the transport sector, it is necessary to address these barriers

Table 3. Percentage distribution of transport activities and properties of immigrants

Parameter	Definition	Immigrants [%]		
		≤1 year	1< year <5	≥5 years
Driving license	no license	38.9	19.3	14.3
	have license	61.1	80.7	85.7
Transportation mode	public transport	55.6	64.7	77.8
	private vehicle	11.1	14.3	6.4
	bicycle/walking	16.7	5.9	1.6
	other	0.0	0.8	1.6
	public and private	5.6	5.0	1.6
	public and bicycle	5.6	0.8	0.0
	private & bicycle	0.0	1.7	1.6
	public and other	0.0	1.7	1.6
Vehicle ownership	no vehicle (0)	61.1	41.2	28.6
	car (1)	0.0	29.4	34.9
	motorcycle (2)	0.0	14.3	12.7
	bicycle (3)	22.2	7.6	3.2
	scooter (4)	5.6	0.0	1.6
	multiple vehicles (1 and 2)	0.0	0.8	1.6
	multiple vehicles (1 and 3)	5.6	1.7	12.7
	multiple vehicles (1 and 2, and 3)	0.0	0.0	0.0
	multiple vehicles (2 and 3)	0.0	1.7	0.0
Public transport	better in the home country	11.1	22.7	22.2
	similar	66.7	60.5	63.5
	better in Turkey	22.2	16.8	14.3
Road quality in cities	better in the home country	77.8	68.1	57.1
	similar	22.2	27.7	39.7
	better in Turkey	0.0	4.2	3.2
Driver and pedestrian	better in the home country	11.1	18.5	17.5
	similar	72.2	65.6	58.7
	better in Turkey	16.7	15.9	23.8
Traffic safety	better in the home country	11.1	17.6	19.1
	similar	72.2	68.1	61.9
	better in Turkey	16.7	14.3	19.1

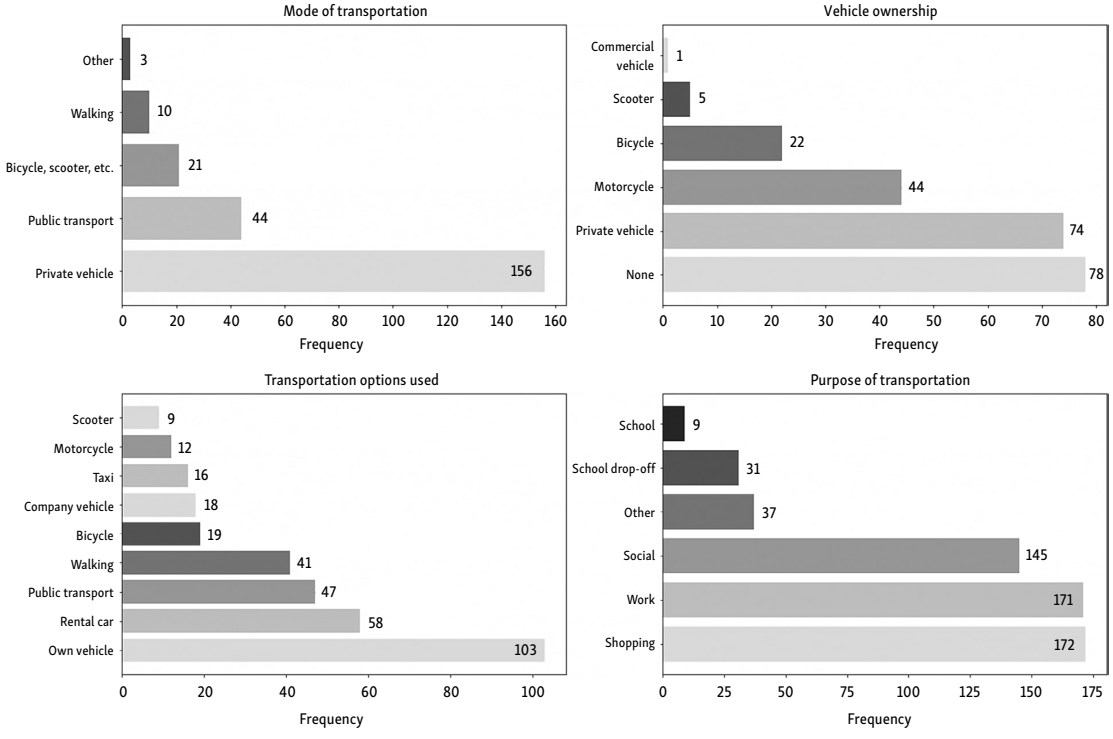

Figure 3. Transportation habits statistics of immigrants

as they affect user satisfaction and the system's overall efficiency. The results also suggest that cost and signage/directions are the most significant issues, whereas accessibility for disabled individuals and safety concerns are less challenging. These insights can guide policymakers to prioritize improvements in cost reduction and better signage while ensuring continued monitoring of less problematic areas.

Figure 5 explores how often people living in Turkey continue using public transportation. Each black point represents information belonging to one person, while the black LOESS smooth line shows the general direction of the scatter. That dark part surrounding the LOESS line denotes its confidence level at 95%. The chart reveals curved trends in public transport over time spent in one place, which shows migrants' adaptation process to that area's transit network complexity.

4. Analysis and findings

The study used a Multiple Linear Regression analysis as a statistical technique to mathematically model the migrants' transport activities. This method examines the interaction between a dependent variable and one or more independent variables. To assess the factors that affect the utilization of public transport in Turkey, equation was defined as given below:

$$y = \alpha + \gamma_1 \cdot x_1 + \gamma_2 \cdot x_2 + \gamma_3 \cdot x_3 + \ldots + \gamma_9 \cdot x_9 + \epsilon,$$

where: the response variable (Public transport utilization) is denoted by y; the parameter α serves as the model intercept; there is total 9 independent variables represented by γ_1, γ_2, γ_3, …, γ_9, which stand for age, education level, time spent in Turkey, living status (Turkey or other countries), permanent living status in Turkey, communication issues, utilization of mobile apps, and language, respectively.

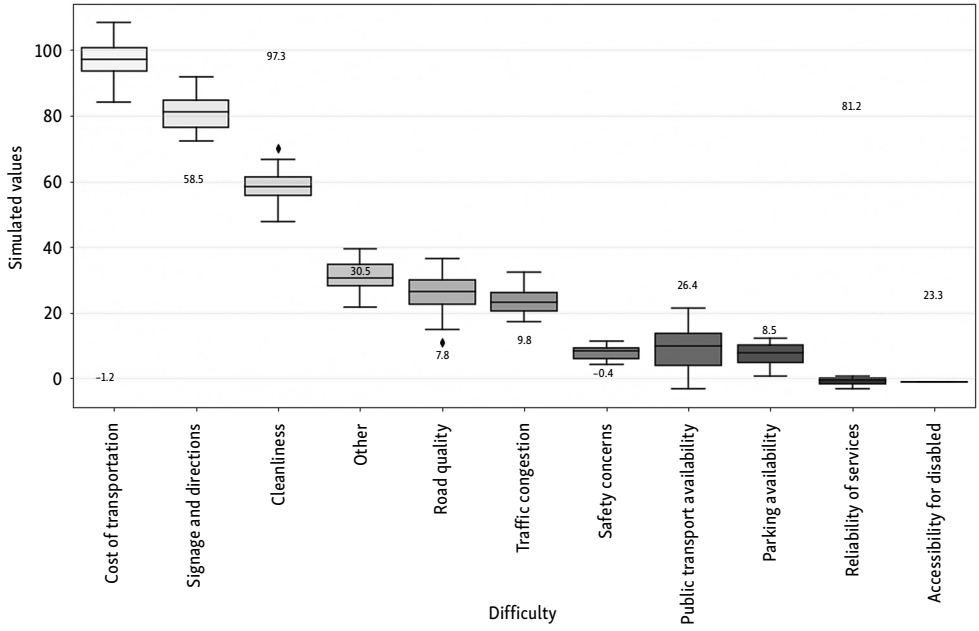

Figure 4. Encountered transportation difficulties in Turkey

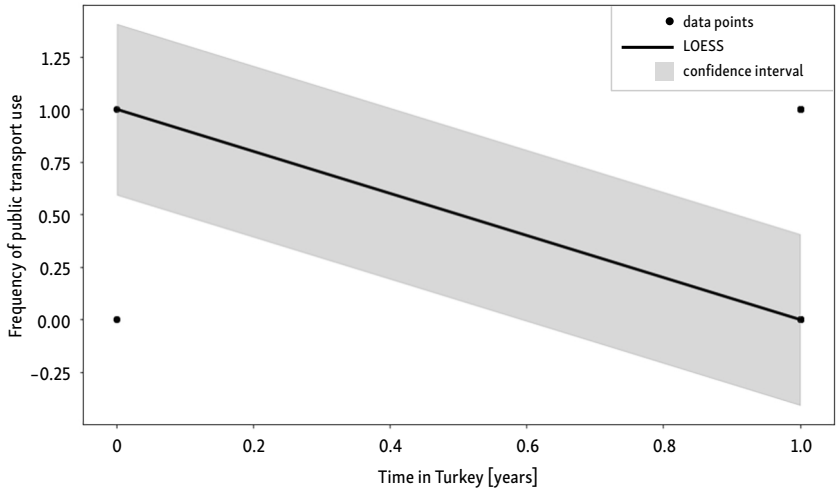

Figure 5. Association between living duration in Turkey and the frequency of using public transport

These coefficients α the relationship between individual predictors and public transport utilization is shown, while ε shows the random error term. With an R^2 value of 0.973, the model has high explanatory power, which means that our selected factors systematically explain the variation in public transport use seen here. Furthermore, correlation metrics in Figure 6 further explain relationships among independent variables; communication issues positively correlate with language issues, and public transport usage is another significant relationship. Therefore, this study provides insights into determinants influencing public transport use and emphasizes the need to deal with language and communication barriers to promote adoption.

In Figure 6, a strong positive correlation was found among communication issues, language issues, use of mobile apps, and public transport utilization. There are very strong correlations (e.g., 0.96, 0.97, 0.93) between language issues, communication issues, utilization of mobile apps, and public transport utilization. This suggests these factors are interrelated, possibly reflecting that individual facing language or communication barriers may also struggle with using mobile apps for public transport. A moderate to weak correlation for living duration in Turkey. It shows a weak positive correlation with public transport usage (0.15). This suggests that the longer people living period in Turkey, the more familiar they become with public transport. However, it does not correlate strongly with other factors like language issues or communication issues. From the heatmap, negative correlations were found for permanent residence status and public transport utilization. There are weak to moderate negative correlations with factors like language issues (–0.24) and communication issues (–0.22). This indicates that individuals with permanent residence status may face fewer challenges in these areas. Public transport utilization shows weak negative correlations with age (–0.08) and gender (–0.03), suggesting these factors have minimal impact on transport utilization. From the heatmap, it was also seen that several variables, such as education level and residence status, show near-zero correlations with others, indicating limited relationships in this context.

The study also performs a factor analysis to compare the relationships between many variables and groups. The main purpose of the analysis is to express the structure that can be described with a large number of variables using a smaller number of factors by revealing the unobservable factors behind a large number of observed variables. A factor analysis on a subset of the surveyed immigrant population's behavioural and demographic data was performed to find underlying factors that explain the observed correlations among these variables. The characteristics were analysed using demographic variables (age, gender, etc.), behavioural variables (residence status, marital status, etc.) and vehicle ownership. 2 factors were retrieved from the factor analysis and indicated in the converted factor space to demonstrate the relationships between the individuals. The plot used markers and shades of grey for the 3 groups categorized according to permanent residency status to guarantee clarity and distinguish-

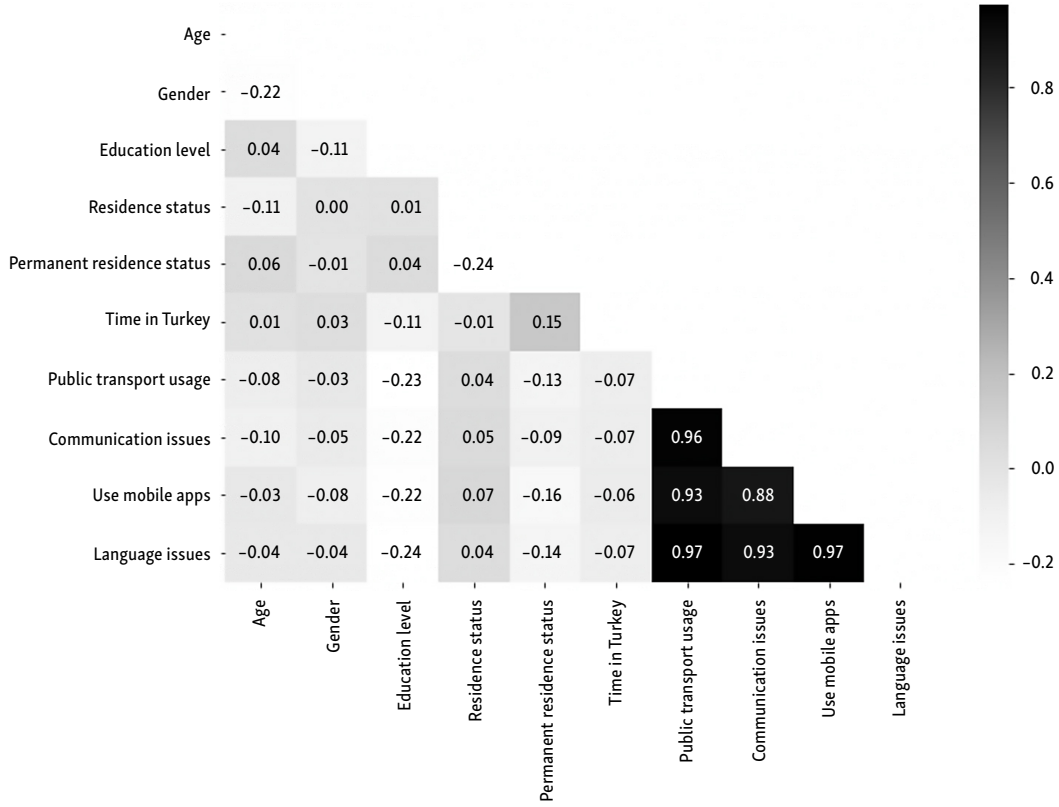

Figure 6. Pearson Correlation heatmap among immigrant characteristics

ability in printed formats. The obtained factor analysis results are given in Figure 7, where each point represents an individual, and the markers and shades can observe their group categorization. Through these maps, it can be seen that people cluster together among themselves based on certain factors. The sphericity test by Bartlett's Test purpose was done to verify the hypothesis claiming that the correlation matrix is equivalent to an identity matrix. Its results were statistically significant ($\chi^2 = 2125.67$, $p < 0.001$), which implies that the variables are interrelated for factor analysis. A KMO measure of sampling adequacy was computed to evaluate whether or not factor analysis was appropriate. An approximate KMO value of 0.82 demonstrated that the data were excellent for factor analysis, while a KMO value of less than that means that the data may not be adequate for factor analysis. Results from factor analysis showed a coherent structure throughout the data set. The significant Bartlett's test confirmed that relationships among variables were sufficiently strong to allow for factor analysis, while the high KMO value also favours this analytical approach with our dataset. Such results suggest possible dimensions objectively existing behind demographic features of migrants' behaviour.

A cluster analysis was also conducted to reveal unobservable hidden structures in data by grouping data with similar characteristics. This method creates groups or clusters among observations when the data are not divided into predetermined classes. Cluster analysis groups the

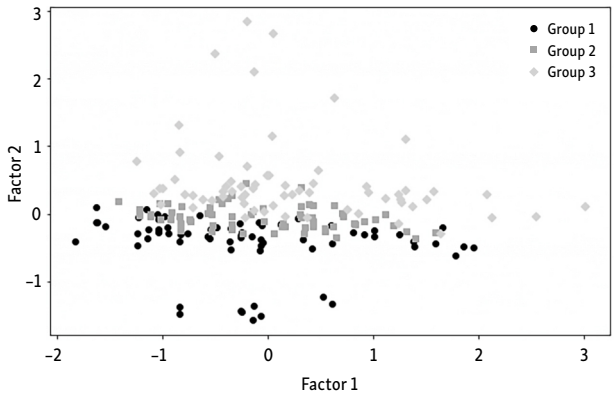

Figure 7. Factor analysis results to compare the relationships between many variables and groups (Group 1 – demographic variables; Group 2 – behavioural variables; Group 3 – vehicle ownership)

data similarly by evaluating the similarities and differences between the observed data. In Figure 8, a presentation has been prepared on how survey data has been clustered based on Cluster 1 as demographic variables (age, gender), Cluster 2 as behavioural variables (education level, residence status, permanent residence status, time spent in Turkey, marital status, number of children) and Cluster 3 as vehicle ownership of the immigrants. The application of *k*-means clustering with 3 clusters is markedly distinct, and this can be readily discerned by visualizing the results with PCA. This approach enables the examination of the vari-

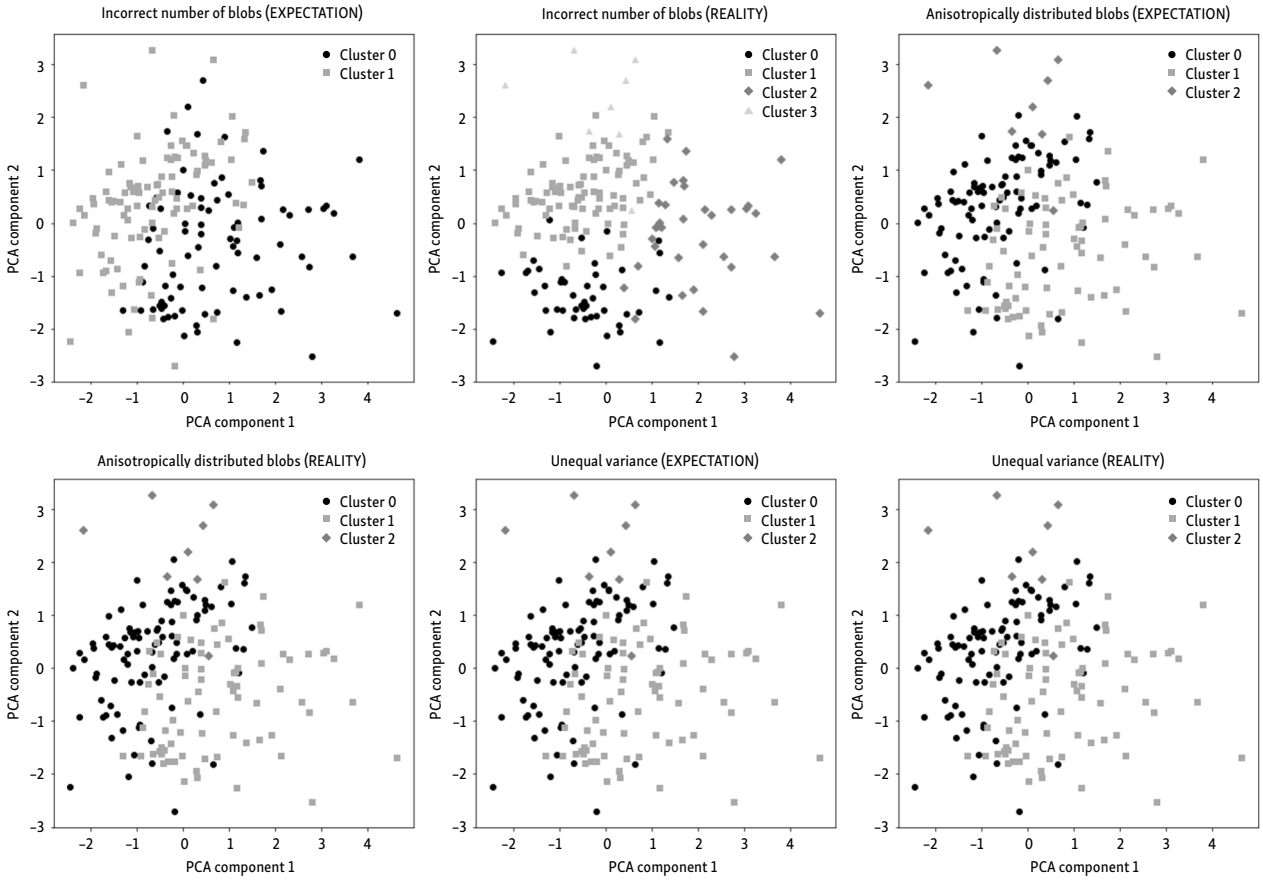

Figure 8. Cluster analysis of survey participants

ability in clustering outcomes under different assumptions, thereby underscoring the significance of this technique. The application of PCA to examine anisotropic distributions and unequal variances reveals significant patterns captured by meaningful separation of clusters on graphs. This indicates that these 2 aspects are of great importance when modelling the underlying structure of any dataset. The outcome of this modelling is of great interest. The clusters identified represent various subgroups of migrants exhibiting specific demographic characteristics and behavioural disorders. This kind of study is essential as it offers a reference point for future research on gaps within the migrant community, which enriches the migration field.

A DTC was used to classify data or make predictions through regression. The decision tree makes decisions by dividing the data into a tree structure and passing the results step by step through the branches to the final leaves. This algorithm expresses complex decision processes in a simple and understandable tree structure (Figure 9).

The DTC was employed to predict the likelihood of obtaining permanent residence based on various factors, including age, gender, time in Turkey, and usage of mobile apps for transportation. The PDT in Figure 9 highlights the key factors determining permanent residence status. The model identifies age as the most significant predictor, with the initial split occurring at age 20. Further splits based on age refine the classification, indicating that younger individuals are more likely to be classified differently from older ones. This pruned tree simplifies the analysis by focusing on the most influential factor, offering clear insights into how age affects the likelihood of obtaining permanent residency. A DTC was employed to predict the probability of getting a permanent residency status depending on factors such as age, gender, time spent in Turkey, and use of mobile transportation applications. The PDT in Figure 9 determining factors for permanent residency status, presenting that age is the most significant predictor. The significance is seen in the fact that age is used as the 1st split at 20 for this model. This pruned tree provides a more straightforward way to analyse data by cantering on one most important variable: age presents us with no difficulties for certain in our view of attaining permanent residency status.

The decision tree analysis in Figure 9 highlights that age is the most influential factor in determining migrant status. Younger migrants (≤26.5 years) are predominantly classified as permanent residents, with only a small percentage identified as non-permanent. However, among young males (≤25.5 years), there is a higher likelihood of being non-permanent (22%), suggesting that they may be more transient due to job or study opportunities. This group likely relies on flexible mobility options such as public transport, bike-sharing, or short-term rental services. In contrast, middle-aged migrants (26.5…54.5 years) show a strong tendency toward Permanent residency (98%), reflecting more stable commuting patterns, possibly favouring private vehicles or long-term public transport subscriptions.

For older migrants (54.5+ years), the classification becomes more uncertain, with some showing an equal probability of being permanent or non-permanent. This suggests that factors such as retirement, legal residency, or family reunification may play a role in their migration decisions. Their transport needs are likely shifting toward reduced mobility, government-subsidized transport options, or specialized senior transport services. Overall, the findings indicate that younger migrants have more dynamic mobility patterns, while older, settled migrants tend to establish long-term transport habits, influencing urban transport planning and policy-making.

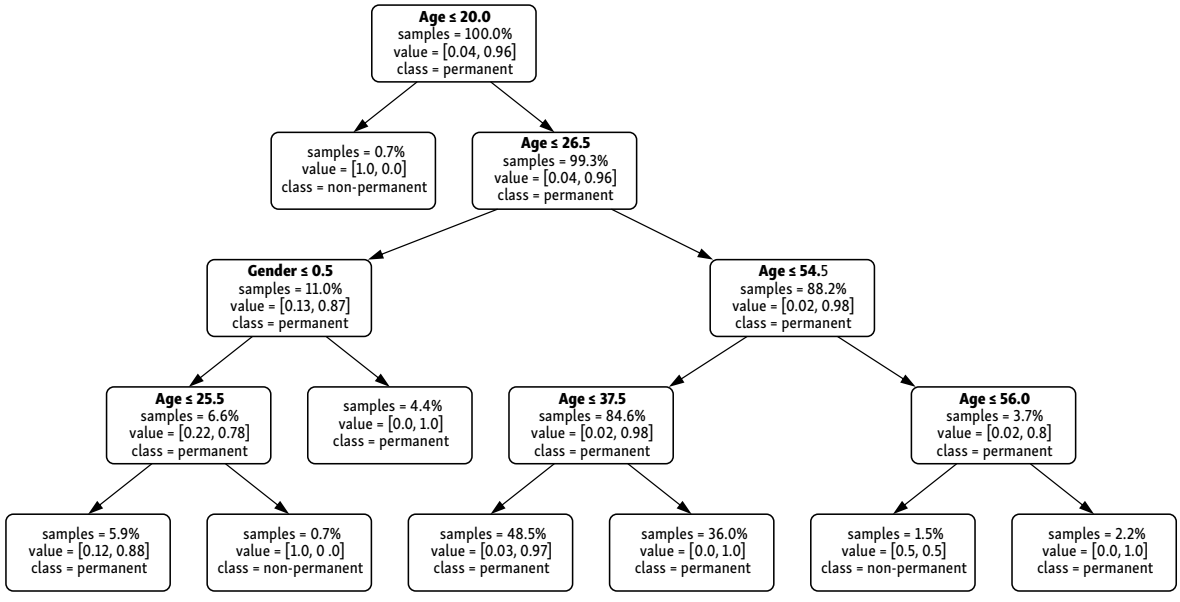

Figure 9. DTC to predict permanent resident status

5. Suggestions for a better adaptation of immigrants

Using the obtained results, the study proposes given suggestions to supply immigrants' adaptation to current transport system and structure of Turkey under given subtitles:

- reducing transportation costs:
  - implementing affordable public transport pricing schemes, especially for low-income immigrant communities, could enhance accessibility and encourage greater utilization;
  - subsidy programs or travel passes tailored to immigrants could mitigate cost-related challenges;
- improved signage and multilingual information:
  - upgrading traffic signage and incorporating multiple languages, particularly in areas with high immigrant populations, would significantly improve navigation and ease of use;
  - introducing multilingual mobile apps with real-time traffic updates and public transport schedules can enhance accessibility;
- awareness and training programs:
  - conducting workshops or campaigns to familiarize immigrants with the local transport culture, systems, and rules could accelerate the adaptation process;
  - providing user guides and training sessions on mobile app usage for transport-related purposes would address technological barriers;
  - infrastructure enhancements:
  - improving road quality and ensuring better safety measures for both drivers and pedestrians could positively impact immigrants' perceptions of the system;
  - expanding cycling and walking infrastructure to promote sustainable and cost-effective alternatives for short-distance travel;
- policy and stakeholder collaboration:
  - local authorities, transportation agencies, and civil society organisation should work together to design immigrant-focused transport policies that address unique challenges and foster inclusivity;
  - periodic feedback mechanisms like surveys should be implemented to monitor satisfaction levels and evolving needs;
  - inclusion of social integration measures:
  - transportation policies should be aligned with broader social integration strategies, ensuring that immigrants feel welcomed and supported in all facets of urban life.

By addressing these challenges, policymakers and planners can create a more inclusive and efficient transport system, ultimately benefiting not only immigrants but the wider population. This study serves as a valuable foundation for future research and a practical guide for decision-makers striving to improve immigrant transportation experiences in Turkey and beyond.

6. Conclusions and discussion

Political crises, wars, civil unrest, economic problems, and various other factors worldwide can lead to significant migration to be safer or more liveable. Especially over the past century, advancements in technology and transportation infrastructure have facilitated migration movements involving millions of people. Due to its geopolitical location and the conflicts occurring along its borders, Turkey has experienced substantial waves of migration in recent years. As a result, people with diverse religions, languages, races, and ethnic origins have begun living together within its borders. Numerous organizations and institutions have provided significant economic assistance to support integration of immigrants into Turkey's transportation infrastructure.

This study provides a comprehensive analysis of the transport adaptation behaviours of immigrants in Turkey, highlighting key factors that influence their integration into the transportation system. The findings indicate that while many aspects of Turkey's transport infrastructure are familiar to immigrants, significant barriers such as high transportation costs (identified as the most critical issue by respondents), inadequate traffic signalization, etc., hinder their complete adaptation. The results also reveal that demographic and socio-economic characteristics, particularly age, education level, and cultural similarities, play a crucial role in shaping transport preferences. Younger migrants (≤26.5 years) and those with a higher level of education adapt more quickly, whereas older migrants (≥54.5 years) and those from diverse cultural backgrounds face more significant challenges. Additionally, the longer immigrants reside in Turkey, the more integrated they become into the public transport system, with their reliance on public transportation increasing over time.

Statistical analyses, including multiple linear regression and DTC, confirm that age is the most significant predictor of migration permanence and transport habits. The decision tree analysis reveals that young males (≤25.5 years) are more likely to be transient migrants, relying on flexible transport options such as public transit, bike-sharing, or rental vehicles. In contrast, middle-aged migrants (26.5...54.5 years) demonstrate more stable commuting patterns, with a higher likelihood of private vehicle ownership or long-term public transport utilization. Additionally, public transport accessibility and affordability significantly impact transport choices, with most immigrants using public transport (77.8%) as their primary mode of mobility. However, vehicle ownership rates increase with the length of stay, with 34.9% of long-term immigrants owning a car, compared to none among newcomers. Correlation and factor analyses further highlight the interconnectedness of language barriers, communication challenges, and public transport utilization. Immigrants facing language difficulties struggle more with mobile transport applications, leading to lower confidence in navigating the system. The

negative correlation between permanent residence status and reliance on public transport suggests that as migrants settle permanently, they transition towards private mobility solutions. Furthermore, cluster analysis identifies 3 primary migrant groups based on demographic variables, behavioural characteristics, and vehicle ownership, reinforcing the diversity of transport needs among immigrant populations.

The study emphasizes the need for targeted policy interventions to enhance immigrant transport adaptation, including reducing transportation costs, improving multilingual traffic signalization, providing cultural orientation programs, and expanding mobility infrastructure. Addressing these issues would not only facilitate the social and economic integration of immigrants but also contribute to the overall efficiency and inclusivity of Turkey's transport system. The study's findings serve as a valuable resource for policymakers, urban planners, and transport authorities, offering practical recommendations for improving immigrant mobility experiences. Future research could explore longitudinal changes in immigrant transport behaviours and the impact of digital solutions, such as multilingual mobile apps, in assisting their adaptation. By ensuring that transportation systems are accessible, cost-effective, and culturally inclusive, urban mobility policies can play a crucial role in fostering social cohesion and economic participation among immigrant populations.

Author contributions

Metin Mutlu Aydin and *Eren Dağli* conceived the study and were responsible for the design and development of the data analysis.

Metin Mutlu Aydin, *Eren Dağli* and *Mehmet Sıddık Çadirci* were responsible for data collection and analysis.

Metin Mutlu Aydin and *Mehmet Sıddık Çadirci* were responsible for data interpretation.

Eren Dağli wrote the 1st draft of the article.

Disclosure statement

No potential conflict of interest was reported by the authors.

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