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THE IMPACT OF SOCIO-DEMOGRAPHIC INDICATORS ON URBAN SHOPPING TRIP PARAMETERS

Understanding the factors influencing a user's choice of mode and travel time within an urban transport system is a crucial element of urban mobility research. This study focuses on the characteristics of shopping trips, which are less time-regulated compared to work or school commutes but have a significant impact on urban traffic flows. The aim of the research was to identify the connections between socio-demographic indicators and people's choice of place and time for shopping. An online survey was conducted among residents of Lviv, yielding 152 responses suitable for further analysis. The results indicate that the likelihood of using transport is much higher when shopping at large malls or markets (64.2%) compared to shopping at smaller stores (31.3%). Most shopping trips are made in the afternoon (after 3:00 p.m.). The study of the influence of socio-demographic characteristics on the choice of shopping location and time was carried out using the cross-tabulation method, followed by a χ^2-test to verify the hypothesis of variable independence. According to the results, car ownership significantly influences the choice of shopping location, while gender and household income affect the choice of shopping time. A further cluster analysis based on statistically significant indicators, using the k-means method, identified five population clusters with distinct preferences for shopping time and location. These findings are valuable for modeling shopping trip demand and distribution over time and space.

Keywords: shopping trip, shopping time, shopping place, cluster analysis, socio-demographics indicators

INTRODUCTION

Studying population demand for transportation is a crucial element for understanding the factors influencing it, assessing and planning urban transport system parameters, finding ways to promote sustainable urban mobility, and developing measures that encourage such mobility.

The purpose of a trip plays a key role in evaluating and forecasting transportation demand, especially when analyzing its distribution across different times of day and spatial orientation [1, 2]. Work and educational trips are usually time-concentrated and, due to their specific nature, often require the transport system to adapt to their demands. On the other hand, trips for other purposes tend to offer more flexibility in terms of time and direction and are more influenced by individual behavioral habits and preferences. This is particularly relevant to shopping trips [3].

The transition to sustainable mobility is a complex process that requires the involvement of various stakeholders, from businesses to policymakers. It involves numerous actions related to legislative decisions, automotive manufacturing, land use, and transport infrastructure planning. However, there is a growing body of research emphasizing that changes in population travel behavior can have a decisive impact on the implementation of sustainable mobility models [4].

ANALYSIS OF LITERATURE DATA AND FORMULATION OF THE PROBLEM

Since shopping trips are among the most common types of trips [5], transport researchers are particularly interested in understanding their impact on the volume of population movements. In general, several research directions can be distinguished in this field:

-Modeling demand for shopping trips [6].
-The impact of land use parameters on consumer behavior [7].
-The effect of online shopping on demand for physical shopping trips [8].
-The study of factors influencing the mode choice for shopping trips [9].

Table 1 presents the results of a literature review focusing on urban shopping trips.

Table 1. Research on the parameters of urban shopping trips

References	Research task	Considered indicators	Using methods
Bhat & Steed, 2002 [10]	Development of a departure time choice model for shopping trips	Socio-demographic indicators, type of purchase, start location of the shopping trip (home/non-home)	Baseline hazard function with a non-parametric form
Saito & Yamashiro, 2018 [11]	Estimation of the cost of	Socio-demographic indicators, place of	-

	a shopping trip	purchase	
Ma & Cao, 2019 [12]	Mode choice for a shopping trip	Socio-demographic indicators, shopping place frequency	Structural equation modeling
Jonker & Venter, 2019 [13]	Predicting the length of a shopping trip (by car)	Type and size of the shopping center	Data analysis of mobile GPS loggers
Ramos et al., 2020 [14]	The frequency of using the car for trips (depending on the purpose of the trip)	Socio-demographic indicators, city size, attitude to driving	Factor analysis, linear regression
Zhuk et al., 2020 [15]	The likelihood of choosing a PT for a shopping trip	Socio-demographic indicators, weekday, trip duration	Classification decision trees
Yamada & Hayashida, 2020 [16]	The correlation model between the duration of a shopping trip and the length of stay at the place of purchase	Socio-demographic indicators, shopping trip duration, shopping duration	Cluster analysis, multiple regression
Arranz-López et al., 2023 [17]	Choice of shopping place (online or offline)	Socio-demographic indicators	Fractional regression

It is worth noting that most existing studies of shopping trips focus on assessing the impact of different factors on the choice of trip mode, but usually, a person first chooses a place to buy and then the mode of travel to that place. We also found a limited amount of literature that examines the time of such trip.

RESEARCH QUESTIONS

Based on the literature review, the following research questions are formulated:

1. RQ1. What are the peculiarities of the purchasing behavior of the population of a large city with a significant density of possible places to make a purchase?

2. RQ2. What socio-demographic indicators of the population influence the choice of the place of purchase and the time of the shopping trip?

RESEARCH RESULT

To collect data for the study, an online questionnaire was developed (available at https://forms.gle/eHQtGPBdvKBf4Fue8). The questionnaire consists of three parts: questions about general shopping behavior (frequency of food and non-food purchases, preferred shopping location, and mode of travel), questions about the last offline purchase (place, time, amount, mode of travel), and a block of respondent sociodemographic characteristics. The survey was conducted between March and June 2024. As a result, 323 responses were received, including 152 from Lviv residents. Since population density and land use characteristics differ in urban and rural areas, it is incorrect to generalize survey data on the purchasing behavior of residents of such areas. Therefore, for this study, we selected a part of the sample consisting of respondents who indicated Lviv as their current place of residence. Lviv is a large city with a population of over 717 thousand people and a population density of over 4816 people/km^2 (official statistics as of February 01, 2022; no newer data are available, but internal migration processes related to the war have increased the population in Lviv).

The survey sample comprises 59 men (39%) and 93 women (61%). Among the respondents, 50% are young people under the age of 20, 23.7% are aged 21-30, 13.8% are aged 31-40, and 12.5% are over 40. Among them, 31% are employees, and 62% are students. 52.6% also own a car. Table 2 shows the sample distribution by household size and income level.

Table 2. Some sociodemographic characteristics of the sample

Income level	1 (<8000 UAH)	2 (8000-14000 UAH)	3 (14000-20000 UAH)	4 (20000-30000 UAH)	5 (30000-40000 UAH)	6 (>40000 UAH)
Share of sample, %	20.4	13.2	12.5	11.8	13.2	28.9

Household size	1 (living alone)	2	3	4	5 (5 and more members)	
Share of sample, %	17.8	19.1	18.4	29.6	15.1	

The majority of respondents (almost 84%) indicated a small store or market as their main place of purchase of food products (Fig. 1a). Non-food products are also more often bought in small shops or markets, but the difference with other places of purchase is not so big (Fig. 1b).
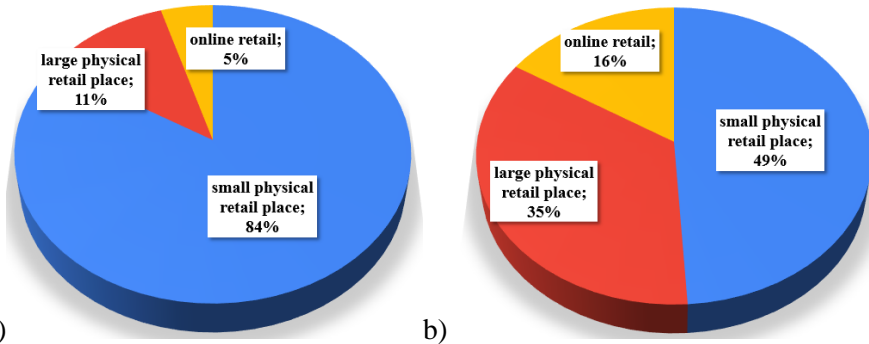

Fig. 1. Preferences shopping place: a) for food products purchase; b) for non-food products purchase

The type of purchase and the purchase place are related to other purchase parameters, in particular, the time and method of travel for the shopping (Fig. 2). This is important information for assessing the impact of shopping trips on the volume and distribution of correspondence in the urban area.
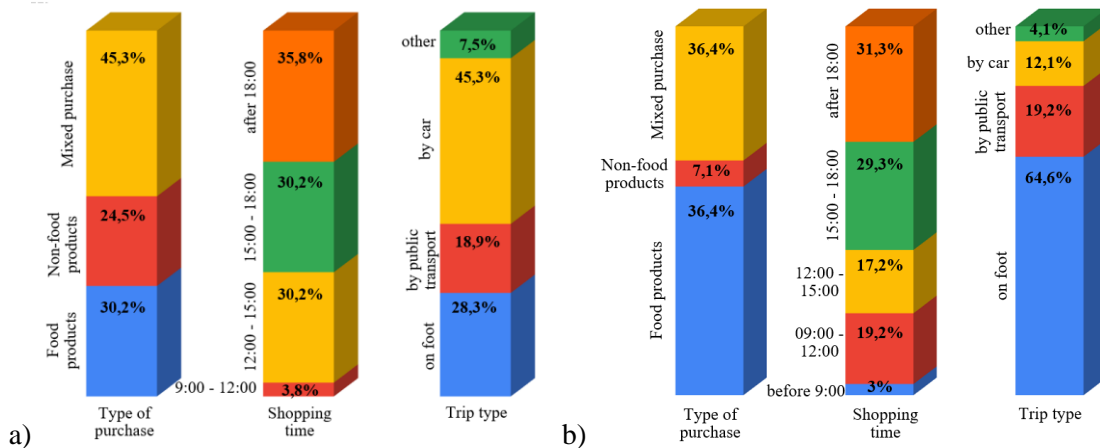

Fig. 2. Main shopping trip parameters: a) large physical retail place; b) small physical retail place

The frequency of using transport for shopping trips is much higher if you shop in a large shopping center or market: 64.2% (of which 45.3% use private transport) vs. 31.3% (of which 12.1% use private transport). The logical explanation is the lower density of large shopping centers and markets compared to small shops and, accordingly, the lower likelihood for a user to have such a place to shop within walking distance. More than half of the respondents make purchases in the afternoon (after 15:00). This percentage is slightly higher for shopping in large shopping centers or markets: 66% vs. 60.6%.

To study the influence of socio-demographic characteristics of the population on the choice of place and time of purchase, for each pair "socio-demographic characteristic - purchase characteristic", we built contingency tables with the subsequent χ^2 test (to test the hypothesis of independence of variables). Such tables are used to analyze the results of surveys where data are presented in the form of categorical variables [18].

Contingency tables show the change in the frequency of occurrence of certain values of one variable depending on the change in the values of another variable. For example, according to the contingency table of the relationship between respondent's gender and place of shopping (Table 3), the survey sample includes 59 men, 41 of whom usually shop in a small shopping center/market and 18 of whom usually shop in a big

shopping center/market, and 93 women, 58 of whom usually shop in a small shopping center/market and 35 of whom usually shop in a big shopping center/market.

Table 3. Contingency table for a pair of variables "Gender – Shopping place"

Value	Shopping place		Sum
Gender	small shopping center/market	big shopping center/market	
Male	41	18	59
Female	58	35	93
Sum	99	53	152

To conduct a χ^2 test, you first need to calculate the expected (theoretical) frequencies, which are valid for the case when the hypothesis of independence of the variables under study is true [19]:

$$E_{ij} = \frac{R_i \cdot C_j}{N} \tag{1}$$

Where R_i - the sum of observed frequencies in the i-th row;

C_j - the sum of observed frequencies in the j-th column;

N - the total number of observations.

The value of χ^2 is determined by the formula [19]:

$$\chi^2 = \sum \frac{(O_{ij} - E_{ij})^2}{E_{ij}} \tag{2}$$

Where O_{ij} - the observed frequencies.

Results for a pair of variables "Gender – Shopping place" are presented in Table 4.

Table 4. Expected frequencies and the value of χ^2 for a pair of variables "Gender – Shopping place"

Value	Expected frequencies for shopping place		The value of χ^2 for shopping place	
Gender	small shopping center/market	big shopping center/market	small shopping center/market	big shopping center/market
Male	38.4	20.6	0.17	0.32
Female	60.6	32.4	0.11	0.20
Sum			0.81	

The calculated χ^2 value is compared to the critical value for the selected significance level and number of degrees of freedom. For the pair of variables "Gender - Shopping place", the number of degrees of freedom is df = 1. The critical value of χ^2 for the significance level α = 0.05 is 3.81, for α = 0.10 χ^2 = 2.71. That is, in this case, the hypothesis about the independence of the preferred shopping place from the respondent's gender is confirmed.

The same calculations were carried out for all pairs of considered variables. The results are summarized in Table 5.

Table 5. Calculation results of the influence of sociodemographic characteristics on the choice of shopping place and time

Variable/number of categories	Place of shopping / 2	Shopping time / 5
Gender / 2	Calculated χ^2 = 0.81 Critical χ^2 (df = 1, α = 0.10) = 2.71 SSR[1] – NO	Calculated χ^2 = 8.22 Critical χ^2 (df = 4, α = 0.10) = 7.79 SSR – YES Cramer's V = 0.23
Age / 4	Calculated χ^2 = 3.88 Critical χ^2 (df = 3, α = 0.10) = 6.25 SSR – NO	Calculated χ^2 = 18.03 Critical χ^2 (df = 12, α = 0.10) = 18.55 SSR – NO
Household / 5	Calculated χ^2 = 0.73	Calculated χ^2 = 18.39

	Critical χ^2 (df = 4, α = 0.10) = 7.79 SSR – NO	Critical χ^2 (df = 16, α = 0.10) = 23.5 SSR – NO
Income level / 6	Calculated χ^2 = 7.98 Critical χ^2 (df = 5, α = 0.10) = 9.23 SSR – NO	Calculated χ^2 = 33.97 Critical χ^2 (df = 20, α = 0.05) = 31.4 SSR – YES Cramer's V = 0.24
Private car owner / 2	Calculated χ^2 = 7.63 Critical χ^2 (df = 1, α = 0.05) = 3.84 SSR – YES Cramer's V = 0.22	Calculated χ^2 = 1.31 Critical χ^2 (df = 4, α = 0.10) = 7.79 SSR – NO
Profession status / 3	Calculated χ^2 = 3.14 Critical χ^2 (df = 2, α = 0.10) = 4.6 SSR – NO	Calculated χ^2 = 7.62 Critical χ^2 (df = 8, α = 0.10) = 13.36 SSR – NO

[1] SSR - statistically significant relationship

According to the obtained results, there is a statistically significant relationship between the three pairs of parameters. The choice of the shopping place is influenced by the presence of one's car, and the time of purchase is influenced by gender and income level. Kramer's test was performed to determine the strength of the relationship between the studied parameters. The obtained results indicate the presence of a moderate relationship between the studied factors (the value of Kramer's V is in the range from 0.1 to 0.3) [19].

A cluster analysis of the data was carried out using a set of variables between which a statistically significant relationship was found (using XLSTAT 2024.2.2.1422). A graph of silhouette estimates for the formed clusters is presented in Fig.3, and the results of ANOVA variance analysis are presented in Table 6.
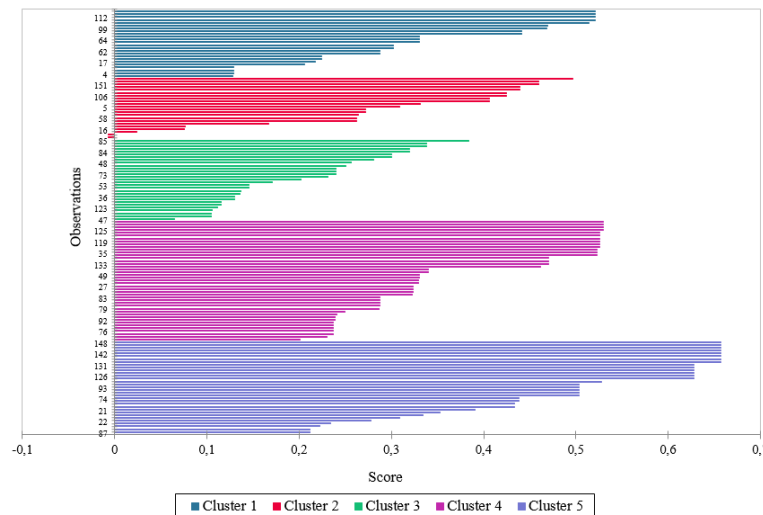

Fig. 3. The graph of silhouette estimates when dividing the sample into 5 clusters (using k-means method)

Table 6. The results of the ANOVA analysis of the variables that are taken into account in the cluster analysis

Variable	Degrees of Freedom - DF (Model)	Mean squares (Model)	DF (Error)	Mean squares (Error)	F-statistic	Pr > F (p-value)
Place of shopping	4	0,847	148	0,212	3,997	0,004
Shopping time	4	33,042	148	0,375	88,161	<0,0001
Gender	4	0,849	148	0,222	3,816	0,006
Private car	4	2,214	148	0,198	11,207	<0,0001
Income level	4	128,316	148	0,327	392,983	<0,0001

Characteristics of the resulting clusters:

-Cluster 1: women with their own car and a high average monthly household income (over 30000 UAH/month). This cluster usually makes purchases in small shops or local markets in the morning and lunch periods (from 9:00 to 15:00).

-Cluster 2: men without their own car and with a relatively low average monthly household income (up to 20000 UAH/month). This cluster also usually shops in small shops or local markets during the morning and lunch periods (from 9:00 to 15:00).

-Cluster 3: women with their own car and an average monthly household income of 14,000 to 30,000 UAH/month. This cluster usually makes purchases in large shopping centers or markets during the lunch and afternoon periods (from 12:00 to 18:00).

-Cluster 4: car owners with a high income level (above 30000 UAH/month), who usually make purchases in the afternoon and evening (after 3:00 p.m.) in large shopping centers or markets.

- Cluster 5: Population with low household income (less than 14000 UAH/month) and without a car), who usually shop in the afternoon and evening (after 15:00) in small shopping centres or markets. This cluster is the clearest (since the silhouette scores have the highest values).

A P-value < 0.05 indicates a significant effect of all variables on clustering results. The variables "time of purchase" and "income level" have the greatest influence, because they have the smallest p-values and, at the same time, the largest F-values. The moderate F values for the variables "place of purchase" and "gender" indicate their smaller influence compared to the other variables.

DISCUSSION OF THE RESULTS OF THE STUDY AND SUMMARY

Shopping is a tangible part of daily trips in urban areas. According to the results of urban mobility studies, the share of these movements in Lviv is 18% [20]. Therefore, studying the purchasing behavior of the population is an important element of studying the travel demand.

In modern conditions, potential buyers have three main options for choosing a place to shop: buy in small shops or markets, which are often within walking distance from home or on the way from home to work/study; buy in large shopping centers or markets; make an online purchase. The results of the surveys conducted in Lviv show that 95% of respondents usually buy food products offline, and 84% buy non-food products offline. When making purchases in large shopping centers or markets, the share of respondents who choose transport for trips is more than 64%. When buying in a small store/market, the share of transport users for trips is 31.3%.

The impact of shopping trips on the functioning of the city's transport system depends on the time and mode of travel. It is obvious that moving with the use of transport, especially during peak periods, contributes to the additional load of the street network. When studying the correspondence of the population, many researchers emphasize the factors of the choice of the trip mode. However, the method of movement depends on the place of purchase. Therefore, in the current study, the place of purchase itself was chosen as the selection parameter.

The assessment of the presence of a correlation between the socio-demographic characteristics of the respondents and the place and time of their typical purchase was carried out using the cross-tabulation method, followed by the calculation of the Chi-square independence criterion. The correlation between owning a car and place of purchase was found to be statistically significant. Gender and average monthly household income affect the time of purchase. Further cluster analysis revealed population groups with pronounced preferences for shopping place and time.

Further research involves the formation of models for choosing the mode of shopping trips and forecasting the distribution of shopping flows in the urban area, considering the density of location and the accessibility of places for shopping.

REFERENCES

1. Alsger, A., Tavassoli, A., Mesbah, M., Ferreira, L., & Hickman, M. (2018). Public transport trip purpose inference using smart card fare data. Transportation Research Part C: Emerging Technologies, 87, 123-137. https://doi.org/10.1016/j.trc.2017.12.016

2. Zhang, Hui, Li Zhang, Yanjun Liu, Lele Zhang. (2023). Understanding Travel Mode Choice Behavior: Influencing Factors Analysis and Prediction with Machine Learning Method. Sustainability, 15/14, 11414. https://doi.org/10.3390/su151411414

3. Černikovaitė, Miglė, Žaneta Karazijienė, Lina Bivainienė, and Valdas Dambrava. (2021). Assessing Customer Preferences for Shopping Centers: Effects of Functional and Communication Factors. Sustainability 13, 6, 3254. https://doi.org/10.3390/su13063254

4.Lanzini, P., Khan, S. A. (2017). Shedding light on the psychological and behavioral determinants of travel mode choice: A meta-analysis. Transportation research part F: traffic psychology and behaviour, 48, 13-27. https://doi.org/10.1016/j.trf.2017.04.020

5.Passenger mobility statistics. Available from: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Passenger_mobility_statistics&stable=0#Data

6.Crocco, F., De Marco, S., Iaquinta, P., & Mongelli, D. W. (2010). Freight transport in urban areas: An integrated system of models to simulate freight demand and passengers demand for purchase trips. International Journal of Mathematical Models and Methods in Applied Sciences, 4(4), 295-273.

7.Handy, S. L., & Clifton, K. J. (2001). Local shopping as a strategy for reducing automobile travel. Transportation, 28, 317-346. https://doi.org/10.1023/A:1011850618753

8.Le, H. T. K., Carrel, A. L., & Shah, H. (2021). Impacts of online shopping on travel demand: a systematic review. Transport Reviews. 42(3), 273–295. https://doi.org/10.1080/01441647.2021.1961917

9.Bouscasse, H. (2018). Integrated choice and latent variable models: A literature review on mode choice. Available from: https://hal.science/hal-01795630/

10.Bhat, C. R., & Steed, J. L. (2002). A continuous-time model of departure time choice for urban shopping trips. Transportation Research Part B: Methodological, 36(3), 207-224. https://doi.org/10.1016/S0191-2615(00)00047-3

11.Saito, S., & Yamashiro, K. (2018). Time value of shopping. Advances in Kaiyu studies: From shop-around movements through behavioral marketing to town equity research, 189-215.

12.Ma, L., & Cao, J. (2019). How perceptions mediate the effects of the built environment on travel behavior? Transportation, 46, 175-197. https://doi.org/10.1007/s11116-017-9800-4

13.Jonker, N. J., & Venter, C. J. (2019). Modeling trip-length distribution of shopping center trips from GPS data. Journal of Transportation Engineering, Part A: Systems, 145(1), 04018079. https://doi.org/10.1061/JTEPBS.0000200

14.Ramos, É. M. S., Bergstad, C. J., & Nässén, J. (2020). Understanding daily car use: Driving habits, motives, attitudes, and norms across trip purposes. Transportation research part F: traffic psychology and behaviour, 68, 306-315. https://doi.org/10.1016/j.trf.2019.11.013

15.Zhuk M.M., Pivtorak H.V., Hits I.I., Kozak M.M. (2020). Prohnozuvannia vyboru vydu transportu u razi miskykh peremishchen na osnovi klasyfikatsiinykh derev rishen. Vcheni zapysky TNU im. V.I. Vernadskoho. Seriia: Tekhnichni nauky, 31 (70), 4, 221 – 226. https://doi.org/10.32838/2663-5941/2020.4/32

16.Yamada, T., & Hayashida, T. (2020). Analysis of shopping behavior characteristics in the Keihanshin metropolitan area in Japan based on a person trip survey. Geo-Spatial Information Science, 23(4), 305-315. https://doi.org/10.1080/10095020.2020.1845984

17.Arranz-López, A., Blitz, A., Lanzendorf, M. (2023). Exploring the associations between E-shopping and the share of shopping trip frequency and travelled time over total daily travel demand. Travel Behaviour and Society. 31, 202-208. https://doi.org/10.1016/j.tbs.2022.11.007

18.Skinner, C. (2019). Analysis of categorical data for complex surveys. International Statistical Review, 87, 64-78. https://doi.org/10.1111/insr.12285

19.Agresti, Alan. (2002). Categorical data analysis. Second Edition. John Wiley & Sons. 710 p.

20.Mobility studies: Lviv, 2021. Available from: https://city-adm.lviv.ua/lmrdownloads/2021/07/Prezz-Mobility%20in%20Lviv%20-2021%20-%20UA%20(1).pdf

***Жук М.М., Півторак Г.В., Маркевич А.І.* Вплив соціально-демографічних показників населення на параметри переміщень міською територією з метою покупок**

Розуміння чинників, які впливають на вибір користувачем міської транспортної системи способу та часу свого переміщення, є важливим елементом дослідження міської мобільності. В роботі акцентується увага на особливостях переміщень з метою покупок, які є менш регламентованими порівняно з робочими чи навчальними поїздками, але мають значний вплив на транспортні потоки у місті. Метою дослідження було визначення зв'язків між соціально-демографічними показниками населення і їх вибором місця та часу для здійснення покупок. Для збору даних проведено онлайн-опитування серед населення міста Львова, в результаті якого отримано 152 придатні для подальшого аналізу відповіді. Результати опитування свідчать, що ймовірність використання транспорту значно вища при покупках у великих торгових центрах або на ринках (64,2%), порівняно з покупками в менших магазинах (31,3%). Більшість покупок виконується у пообідній час (після 15:00 год). Дослідження впливу соціально-демографічних характеристик

населення на вибір ними місця покупки та часу виконання покупки проведено з використанням методу крос-табуляції з подальшим проведенням χ²-тесту для перевірки гіпотези про незалежність змінних. Згідно отриманих результатів, на вибір місця покупок значно впливає наявність власного автомобіля, а на вибір часу — стать та рівень доходу домогосподарства. Подальший кластерний аналіз на основі статистично значущих показників, проведений за допомогою методу k-середніх, дозволив виявити п'ять кластерів населення з вираженими перевагами у виборі місця і часу для покупок. Отримані результати є корисними для моделювання попиту на переміщення з метою покупок та розподілу цих переміщень в часі і просторі.

Ключові слова: переміщення з метою покупки, час покупки, місце покупки, кластерний аналіз, соціально-демографічні показники

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