SHOPPING TRIP MODELLING CONSIDERING THE IMPACT OF MARTIAL LAW

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Resume
The purchasing behavior of the population affects both passenger and freight traffic in cities. On the contrary, indicators of purchasing behavior are influenced by the characteristics of an individual, as well as external factors. The purpose of the conducted research was to analyze the population's purchasing behavior under martial law conditions. Data was collected by surveying residents of Ukraine's rear regions. Multinomial models of the frequency of purchases and transportation choice during shopping were formed. Martial law conditions and changes in the population size in the rear regions, change the general trends in purchasing behavior. The most visible trends are: a significant share of purchases made online, the popularity of shopping close to home, and the tangible impact of owning a car on the frequency and mode of shopping trips. The results obtained may be helpful in predicting consumer behavior in crisis scenarios.

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1 Introduction

Changes in logistical concepts associated with the development of production and changes in consumer expectations imply an increase in the frequency of deliveries, which, in contrast, reduces the required level of stocks and sizes of deliveries and ensures the speed of delivery desired by customers. Conversely, it raises the volume of freight traffic, increasing congestion, pollution and accidents [1]. Transport also consumes many energy resources [2].

Urban freight flows related to shopping consist of three main components [3]:

- movement patterns of the population for shopping in stores (markets, etc.) - shopping mobility,
- trips of commercial transport that delivers goods to stores (to markets, etc.) - shop restocking mobility,
- trips of commercial transport that delivers goods to online buyers - E-purchase delivering mobility.

The global COVID-19 pandemic had a significant impact on the purchasing behavior of the population in many countries, which is confirmed by numerous studies [4-6]. The volume of online purchases, which has already been actively growing since 2010, increased rapidly in 2020. According to the data from Statista, in 2020, the volume of global online sales totaled $4.29 trillion, which is $0.83 trillion higher than in 2019; in 2010, the volume of online trade totaled $572 billion. In 2023, the volume reached $6.52 trillion.

However, possible assumptions that the growth of online trade will significantly reduce the volume of purchases in physical stores are not conclusive at this time. According to previously conducted research, summarized in the work of Le et al. [7], four types of influence of online shopping on the behavior of the population during movements are distinguished:

- online purchases can *substitute* shopping trips (and, therefore, reduce their number),
- online purchases can *complement* shopping trips (and, therefore, increase their number),
- online shopping can *modify* the nature of shopping trips (change of routes, modes of transportation,

destinations, duration of trips, etc.),
- online purchases may not affect shopping trips.

There are still no definitive conclusions about whether substitution or complementation has more influence [8]. Some studies observe the effect of substituting physical shopping with online shopping [9-11], other studies confirm that online shopping complements shopping in stores [12-14]. According to Rai [15], the likelihood that active online shoppers will make fewer shopping trips is potentially limited.

The pandemic and related economic changes have impacted supply chains in general and last-mile logistics in particular [16]. It was the pandemic that highlighted the potential fragility of supply chains in the face of unpredictable risks [17]. However, unfortunately, the COVID-19 pandemic is not the only risk that logistics has faced in recent years. A full-scale Russian invasion of Ukraine in 2022 posed new challenges to supply chains [18-19]. The conditions of martial law impact not only logistical processes but the purchasing behavior of the population, as well.

Traditionally, work-related mobility is considered as the primary movement type in cities. Secondly, depending on the type of settlement, there is mobility related to education, leisure, or shopping. Nonetheless, shopping trips are most interconnected with urban freight traffic. The increase in demand for shopping leads to an increase in demand for delivery of goods to places of purchase, last-mile delivery and, in part, an increase in the volume of garbage removal.

In this paper were examined the peculiarities of the formation of demand for mobility to shop in the rear regions under the conditions of martial law, considering the following features:
- significant population growth in the rear regions due to internally displaced persons (IDPs),

Table 1 *Study of purchasing behavior parameters of the population that affect the frequency of purchases*

Reference	Research purpose	Survey place, sample size	Applied methods	Demographic characteristics	Other characteristics
Ding and Lu, 2017 [13]	correlation between online purchases and in-store purchases	Beijing (China), 537	Structural Equation Modelling	age, gender, occupation type, income level, household size, car availability	presence of a physical store, experience using the Internet
Lee et al., 2017 [12]	correlation between online purchases and in-store purchases	Davis, California, 2000	Pairwise Copula Models	education, occupation type, income level, car availability	shopping attitude factors, level of the physical store accessibility
Maat, K., Konings, R. (2018) [21]	online and in-store purchase frequency modelling	Leiden urban region (the Netherlands), 534	Binary Logit Model, Fractional Logit Model	age, gender, education, occupation type, income level, household size, car availability	goods type (books, clothes, groceries), physical store accessibility
Kalia, P. (2019) [22]	online purchase frequency modelling	India, 308	Chi-square Statistic	age, gender, education, occupation type, income level, marital status	-
Shi et al., 2019 [10]	correlation between online purchases and in-store purchases	Chengdu (China), 710	Regression Analysis	age, gender, education, income level, car availability, cost of living	goods type (clothes and shoes, electronics, food and drink, cosmetics)
Truong and Truong, 2022 [4]	influence of the pandemic	USA, U.S. Census Bureau data	Logistic Regression	age, gender, race, income level, marriage status	fears for health and financial conditions
Arranz-Lopez et al., 2023 [29]	correlation between online and in-store purchases	Germany, Mobilitat in Deutschland (MiD) survey data	Fractional Regressions	age, gender, education, income level	city size and the weekday: working day, weekend

Table 2 *Study of purchasing behavior parameters of the population*

Reference	Research purpose	Survey place, sample size	Applied methods	Demographic characteristics	Other characteristics
Comi and Nuzzolo, 2016 [3]	shopping model sub-system, which combines demand estimation for in-store and online purchases	Rome (Italy), 800	Multinomial Logit Model (MNL), Scenario Forecasting	age, gender, occupation type, household size	goods type (clothing, electronics, hygiene and household products, other goods)
Suel and Polak, 2017b [20]	general model that includes the choice of store, purchase method (offline or online) and shopping trip mode	London (UK), 121	Discrete Choice Modelling, Monte Carlo Method	age	distance to the physical store, cost of delivery when buying online
Russo and Comi, 2020 [24]	modelling the demand for urban shopping trips	Rome (Italy), 200	MNL	age, gender, occupation type, income level, household size	trip characteristic (trip time, accessibility), goods type and weight
Spurlock et al., 2020 [8]	modelling of the choice of receiving the purchase method (delivery or trip)	California (USA), 1012	MNL	age, income level, presence of children in the household	goods type (groceries, clothing, household items, meals), population density
Tao et al., 2022 [28]	changes in purchase behavior under the influence of the pandemic	China, 1742	Regression Analysis	age, gender, education, income level	purchase object, place, timeframe, and method
Vrba et al., 2024 [30]	demand for online shopping (the difference in the buying behavior of local residents and foreign city users)	Czech Republic, 307	MNL	age, gender, foreign city user status	-

- curfew and related restrictions in the work of shopping establishments, public transport (PT) and movement in general,
- suspending trading establishments during the working hours due to air raid alarms or lack of electricity.

In general, in the context of military operations, rear regions are considered to be areas located away from the front line and active combat, providing relative safety for the placement of critical infrastructure, industrial enterprises, and humanitarian aid. The Government of Ukraine, as of 2024, classified seven Ukrainian regions as rear areas (for more details, see section 3.1).

Given the secrecy of most statistical data under martial law, the study's information was collected by conducting questionnaire surveys. The paper is organized as follows. Section 2 presents the results of the analysis of literary sources on the study of the purchasing behavior of the population and modeling of the parameters of demand for purchases. Section 3 describes the results of surveys conducted to study the purchasing behavior of the population of differently sized settlements in the rear regions of Ukraine during the period of martial law. Section 4 presents the results of the formation of logit models of the frequency of purchase and the choice of the mode of transportation when making a purchase, which are the components of the general model of the demand for purchases. A discussion of the obtained results and conclusions is given in Section 5.

2 Literature review

Within the literature review, the focus was on sources related to the study of the population's purchasing behavior and modelling the parameters of demand for purchases (Tables 1-3).

Table 1 presents research focused on modelling the frequency of purchases.

Table 3 presents research aimed at the choice of the mode of transport for the shopping trip.

According to the scientists, the main indicators, characterizing the purchasing behavior, are: the time of purchase, the place of purchase, the method of purchase and the method of movement after the purchase. Purchasing behavior is influenced by the socio-demographic characteristics of an individual, as

Table 3 *Study of purchasing behavior parameters of the population that affect the mode of shopping trips*

Reference	Research purpose	Survey place, sample size	Applied methods	Demographic characteristics	Other characteristics
Meena et al., 2019 [23]	mode choice for shopping mall trip modeling (for economically developing region)	Mumbai, 650	MNL, Nested Logit	age gender occupation type income level car availability	-
Anwari et al., 2021 [25]	purchase frequency and mode choice in shopping trip modelling (impact of the COVID-19 pandemic for economically developing region)	Bangladesh, 572	Ordinal Logistic Regression, Sankey Diagrams	age gender occupation type income level region of living	-
Ramezani et al.,_2021 [26]	mode choice modelling in shopping trips (focused on older adults -aged 55-75)	Helsinki (Finland), 607	Factor Analysis, Integrated Choice and Latent Variable Model	gender income level having a pet living in an apartment	travel time cost and frequency
Zhang et al., 2021 [27]	mode choice modelling in shopping trips (focused on millennials)	Beijing (China), 1555	MNL, latent class model	income level household size car availability presence of children in the household	distance to the store, land use type, attitude to active movement types

well as external factors (characteristics of land use, transport system parameters, etc.).

The work of Suel and Polak [9] includes a review of earlier studies related to the research of buyer behavior in choosing a place of purchase, frequency of purchase and mode of transportation for shopping. In addition, we did not conduct a more detailed review of the literature on the impact of online shopping on travel demand, as this is thoroughly covered in Le et al. [7].

Summarizing the literature review, it is mentioned to note the interest in modelling the behavior of transport systems users considering regional conditions and characteristics. Many studies use an integrated modelling approach, combining several methods for a more comprehensive analysis. The results obtained contribute to understanding the features of urban transport systems' functioning in different conditions and allow for the proposal of measures to increase the sustainability of transport systems.

The analysis also highlights several gaps in existing research. Firstly, only one study was found [30], which concerns Eastern European countries (however, it is worth noting that the search was conducted only among English-language sources). Although the impact on purchasing behavior of differences related to national culture is confirmed, for example, in the studies of Pena-Garcia_et al. [31], which focused on e-commerce and Liobikiene_et al. [32], which investigated "green" shopping. Secondly, apart from studies examining the impact of the COVID-19 pandemic, there are almost no studies conducted in cities (or countries) that examine the long-term effects of a particular risk factor (such as martial law).

3 Data collection and describing

The purpose of the conducted research was to determine the purchasing behavior of the population under long-term conditions of increased risk. To achieve our objectives, we use a step-by-step research approach, as illustrated in Figure 1: conducting a literature review about the study of purchasing behavior parameters of the population (Section 2), data collection using a survey and analyzing research conditions and data results (Section 3), formation of shopping trips model in martial law conditions (Section 4).

3.1 Peculiarities of the functioning of the rear regions of Ukraine under martial law

Russia's full-scale invasion of Ukraine caused, among other things, significant changes in the structure of the population and the displacement of Ukrainians. Millions of people were forced to leave their homes: as of June 2024, there are 3.3 million IDPs [33]. About a quarter of IDPs were received by the rear (according to the classification of the Cabinet of Ministers of Ukraine) western regions of Ukraine (Table 4) - 770 thousand

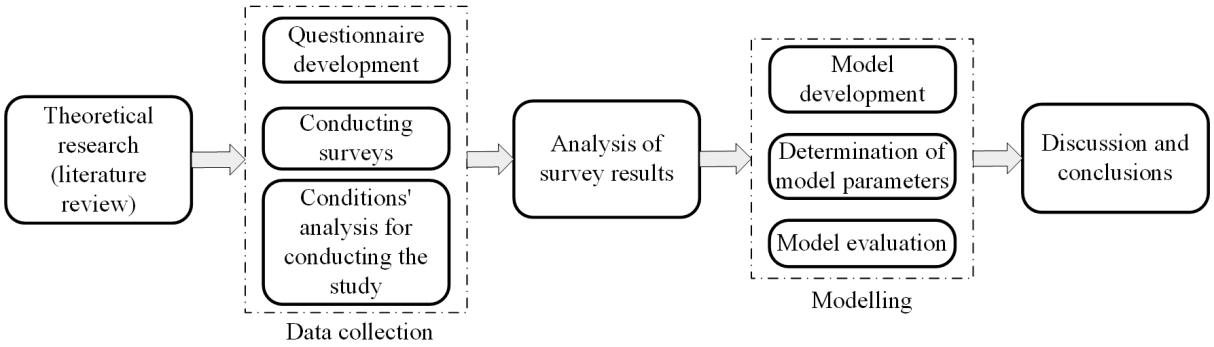
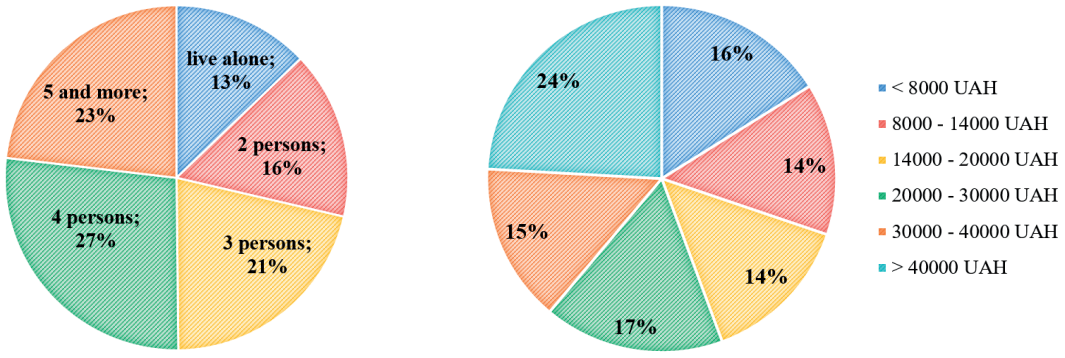


Figure 1 *Stages used in the study*

Table 4 *Some characteristics of the functioning of the rear regions of Ukraine*

Region	Number of officially registered IDPs as of June 2024: thousands of people	Change in population as of June 2024 compared to January 2022	Curfew	The period of PT operation in the regional center
Lviv region	213	+ 8%	00:00 - 05:00	06:00 - 22:00
Ivano-Frankivsk region	116	+9%	00:00 - 05:00	06:00 - 22:00
Ternopil region	66	+7%	00:00 - 05:00	06:00 - 21:00
Zakarpattia region	126	+10%	-	06:00 - 22:00
Volyn region	45	+5%	00:00 - 05:00	06:00 - 22:00
Rivne region	46	+4%	00:00 - 05:00	06:00 - 22:00
Chernivtsi region	88	+12%	00:00 - 04:00	06:00 - 22:00
Khmelnytskyi region	70	+7%	00:00 - 05:00	06:00 - 22:00



a) *b)*

Figure 2 *Structure of the sample of respondents: a) by household size, b) by the average monthly income of the household (during the survey period, 1 euro ≈ 43 UAH)*

people. The actual increase in the population in the rear regions is even higher since some of the people who moved from other regions are not registered as IDPs. The share of women among IDPs ranges from 60% (Rivne region) to 65% (Zakarpattia region), the share of the population aged 18 to 59 years - from 50% (Chernivtsi and Zakarpattia regions) to 60% (Lviv region) [33].

Changes in the parameters of population movements are affected not only by changes in its structure but also by other characteristics typical for martial law, in particular, the curfew and related restrictions on the work of both points of interest and transport.

Among the cities of the western part of Ukraine, Lviv belongs to a category of big cities with a population of more than 500 thousand people. Another seven cities have a population of 100 thousand to 500 thousand people, and 55 cities - from 10 to 100 thousand people. The total share of the urban population is 47% and varies from 37% in the Zakarpattia region to 61% in the Lviv region.

3.2 The structure of the interviewed sample

To collect data on the purchasing behavior of the population, an online questionnaire was created, which consists of three parts: purchasing behavior (frequency and places of purchases of groceries and non-food

products), data on the last purchase and socio-economic characteristics of the respondent. The resulting sample includes 323 responses: 37% from men and 63% from women. Among all the respondents, 54% are residents of Lviv (a large city with a population of more than 500 thousand people), 5% - residents of towns with a population of 100 thousand to 500 thousand people, 22% - residents of cities with a population of less than 100 thousand people and 19% - residents of rural settlements. The average age of respondents is 28 years, and 71% of respondents are under 30 years old. The total of 60% have a personal car in the household. The share of the working population in the sample is 41%, students - 52%. Data on the distribution of the sample of respondents by household size and average monthly household income is presented in Figure 2.

Since the share of residents of medium-sized cities in the sample structure is small, for further analysis, medium-sized and small cities are combined into one group.

3.3 General survey results

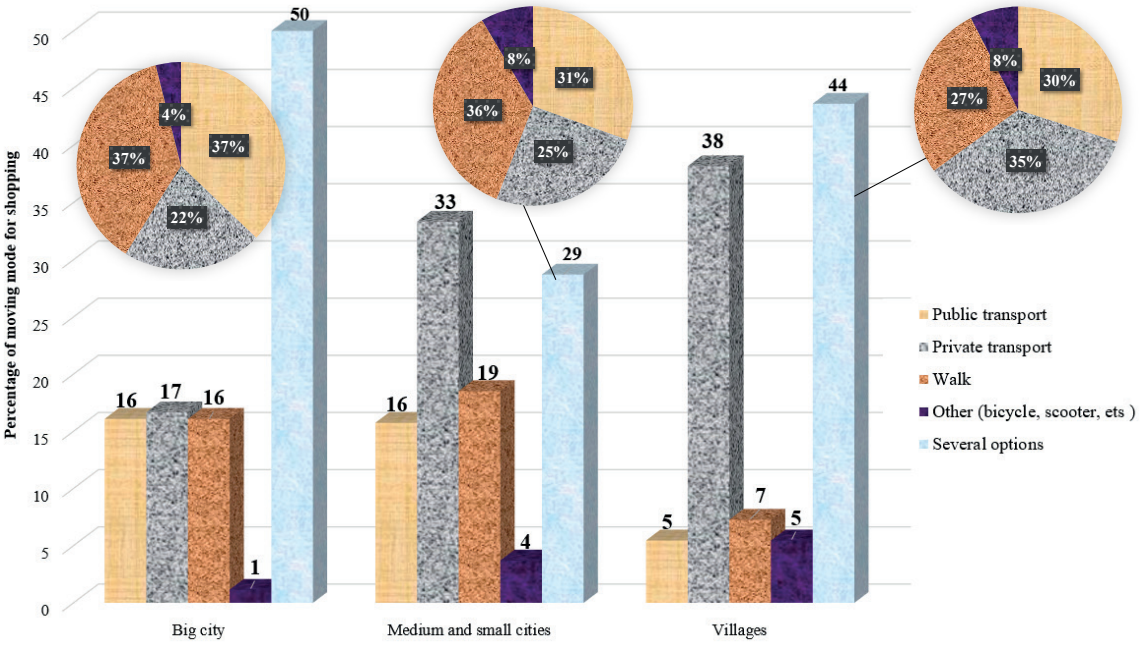
Among the residents of Lviv, half of the respondents chose several options for mode of transportation for the purpose of shopping, which they use with approximately the same frequency (Figure 3). In general, among this share of the population, there is an even distribution of movements by public transport and on foot (16% of respondents chose it as the main mode of movement and 16.5% use it regularly), slightly fewer respondents chose private transport (17% - as the main mode of movement and 11% use it regularly). Among residents of medium-sized and small cities, the majority of trips for shopping are made by private transport (33% of respondents consider it the main way to travel for shopping, and another 7% use it regularly). Among the residents of the villages, trips by personal transport also prevail: 38% chose it as the main type of movement when making purchases, and another 15% use it regularly).

When asked about the mode of transportation during the last purchase, 33% of respondents chose the option “personal car”, 19% chose “public transport”, 41% chose “walking”, and 7% chose the “Other” option.

General trends in frequency of purchases vary by product type. The settlement size has a more noticeable effect on the frequency of purchases of non-food products (Figure 4).

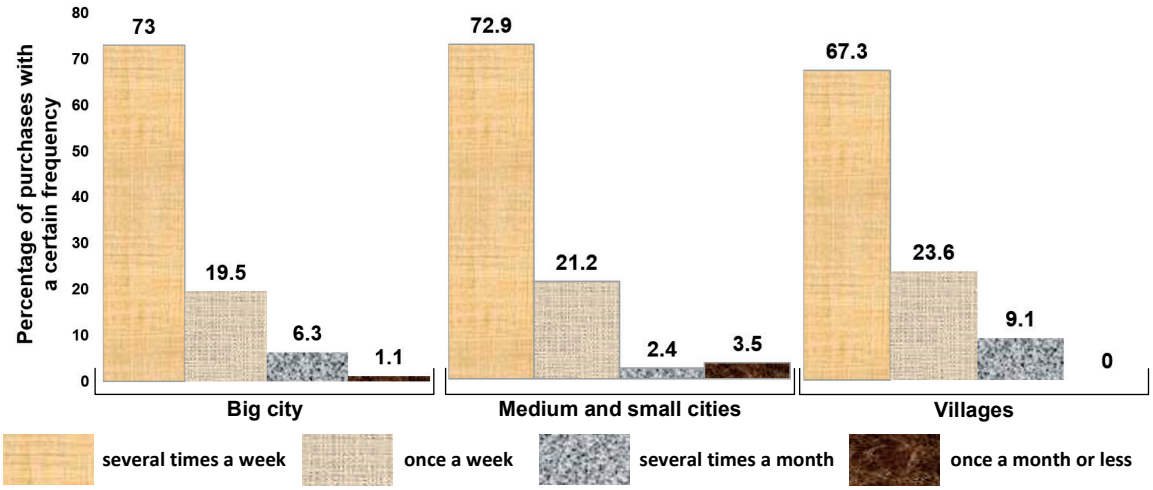
Most respondents shop for groceries several times a week: this is characteristic of 67% of rural residents and 73% of urban residents. Among residents of villages, the percentage of answers “once a week” and “several times a month” is slightly higher compared to residents of cities. This may be due to less available stores (smaller selection, greater distance to the store, etc.). The frequency of purchases of non-food products is expectedly lower: most respondents make such purchases several times a month. However, for residents of medium-sized and small cities, the difference in the frequency of such purchases is the smallest.

Analysis of the data on the popularity of making a purchase in various ways (Table 5) confirms some assumptions made during analyzing the distribution of purchases by frequency. In particular, rural residents are less likely to shop for groceries in stores within walking distance (61% of respondents against 68.5% of

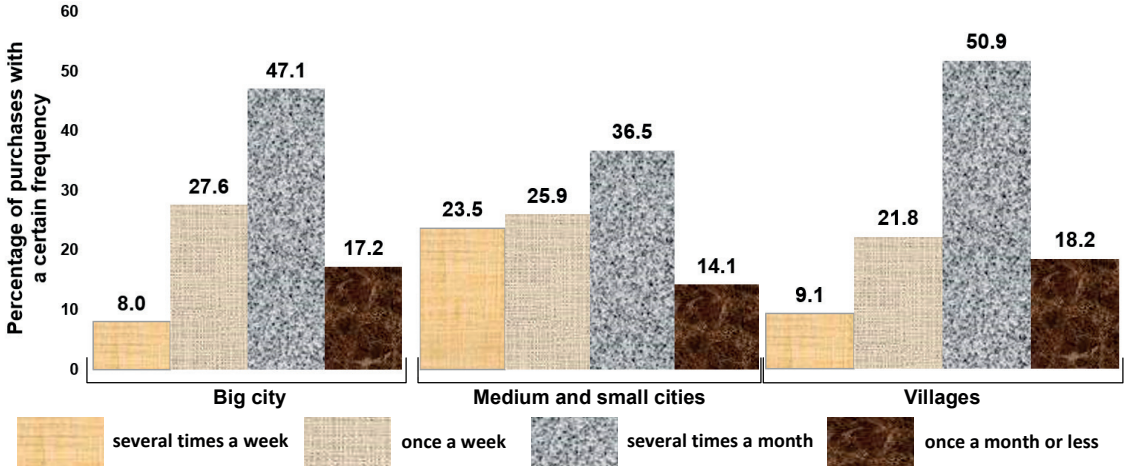


Big cities - cities with population >500 000 people (Lviv), medium and small cities - cities with population < 500 000 people

Figure 3 *Distribution of respondents’ answers regarding the mode of transportation for shopping*



a)



b)

Figure 4 *Frequency of purchases: a) groceries, b) non-food products*

Table 5 *Places where people usually shop (percentage of responses)*

Shopping place	Big cities		Medium and small cities		Villages	
	Groceries	Non-food products	Groceries	Non-food products	Groceries	Non-food products
Shops near the house	71.7	42.4	68.5	38.1	61.0	42.5
Trip to the shopping center	12.5	26.7	14.8	23.8	18.1	21.3
Online-shopping	15.8	30.9	16.7	38.1	21.0	36.3

residents of small and medium-sized cities and 72% of residents of large cities).

Among the respondents, 25% have never made online purchases of groceries and only 8% of non-food products. With a breakdown by the size of the settlement among the residents of Lviv, these values are 33% and 10%, respectively, among residents of medium and small cities - 19% and 6%, respectively, and among the inhabitants of villages - 17% and 9%.

The average purchase size does not differ significantly for residents of different settlements. Most respondents said that a purchase weighing up to 2 kg is "very typical" for them (55% of responses). At the same time, a purchase weighing more than 10 kg was called "very typical" by only 5% of respondents.

4 Results

4.1 Attributes of the travel mode choice model

A multinomial logit model (MNL), based on the utility theory, is used to estimate the parameters of shopping trips [34].

The formed MNL includes four options for mode of movement when making purchases:

- public transport (PuT),
- private transport (PrT),
  walking (w),
  bicycle, scooter, etc. (b).

The formula determines the probability of choosing a certain type of movement:

$$p_{\text{mod}}^{shopping} = \exp(V_{\text{mod}\_i}) / \sum_{i=1}^{4} \exp(V_{\text{mod}\_i}). \quad (1)$$

The benefits of using each of these modes of movement is a function of nine attributes:

$$V_{\text{mod}} = \sum_{i=1}^{9} (\beta_i \cdot attr_i) + asa, \quad (2)$$

where: *asa* - alternative specific attribute,
attr1 - settlement size: 1 - big cities, 2 - medium and small cities, 3 - villages,
*attr*2 - purchase size: 1 - up to 2 kg, 2 - from 2 to 5 kg, 3 - from 5 to 10 kg, 4 - more than 10 kg,
*attr*3 - car ownership: 1 - yes, 0 - no,
*attr*4 - age of respondent,
*attr*5 - gender of the respondent: 1 - male, 2 - female,
*attr*6 - household size: numbers from 1 to 4 correspond to the number of people in a household, number 5 - household size of 5 or more,
*attr*7 - average monthly household income: 1 - less than 8 thousand UAH (≈185 euro), 2 - from 8 thousand to 14 thousand UAH (≈185-325 euro), 3 - from 14 thousand to 20 thousand UAH (≈325-465 euro), 4 - from 20 thousand to 30 thousand UAH (≈465-700 euro), 5 - from 30 thousand to 40 thousand UAH (≈700-930 euro), 6 - more than 40 thousand UAH (≈930 euro),
*attr*8 - professional status: 1 if the consumer is a student, 0 otherwise,
*attr*9 - professional status: 1 if the consumer is employed, 0 otherwise.

The selected attributes characterize the proposed movement alternatives and the individuals (respondents) who make these trips. The relative convenience of each type of movement option depends on the purchase size. The settlement size affects the accessibility of the specific trip options.

4.2 Selection of the model parameters

The model parameters were calculated in the software product XLSTAT 2024.2.2.1422. Statistical quality indicators of the model are provided in Table 6 (Nagelkerke's $R^2 = 0.57$, Count $R^2 = 0.72$).

Low values of Pr > Chi² (<0.0001) in the log-likelihood test, the Score test and the Wald test indicate that the used variables contribute a significant amount of information to the model [35].

Values of model parameters allow for an analysis of the impact of individual attributes on the probability of choosing a certain mode of transportation for shopping. At the value of p > 0.10, a parameter is not considered significant for the model. According to the initial simulation results, the customer's gender is an insignificant parameter, so we decided to exclude it from the model. The final parameters of the model are provided in Table 7. The value of Tolerance > 0.1 indicates the absence of multicollinearity between attributes. When the mode of private transport is a reference modality, then:

Table 6 *Goodness of fit statistics*

Statistic	Chi-square	Pr > Chi²
-2 Log(Likelihood)	152.358	<0.0001
Score	126.941	<0.0001
Wald	78.575	<0.0001

Table 7 *Model parameters (reference modality - private transport)*

Coefficient of attribute	Tolerance	Public transport		Walking		Bicycle, Scooter	
		Value	p (Pr > Chi²)	Value	p (Pr > Chi²)	Value	p (Pr > Chi²)
ß1	0.786	0.005	0.987	-0.511	0.129	1.335	0.004‡
ß2	0.737	-0.721	0.041‡	-0.652	0.041‡	0.403	0.220
ß3	0.843	-3.279	< 0.0001‡	-2.884	0.000‡	-4.686	< 0.0001‡
ß4	0.390	-0.008	0.795	0.019	0.518	-0.094	0.032‡
ß6	0.762	0.022	0.915	0.018	0.927	-0.905	0.001‡
ß7	0.708	-0.307	0.081‡	-0.043	0.804	0.350	0.102
ß8	0.134	-1.141	0.461	-1.433	0.293	-5.105	0.001‡
ß9	0.198	-0.890	0.506	-1.639	0.160	-5.071	0.000‡
asa		6.024	0.010	5.308	0.013	8.077	0.003

‡ - the value of p < 0.10; the most significant parameters

$$\exp(V_{\mathrm{Pr}T}) = 1 + \exp(V_{PuT}) + \exp(V_w) + \\ + \exp(V_b). \quad (3)$$

Owning a car reduces the likelihood of using the public transport, walking, cycling or riding a scooter for shopping. Moreover, owning a car has the most significant negative impact on the likelihood of using bicycles or scooters. In addition, the probability of using own car increases compared to the probability of using public transport or walking with the increase in purchase size (for the bicycle/scooter mode, this attribute does not have a statistically significant impact). The probability of using public transport decreases with the growth of the household's average monthly income. However, income does not affect the change in probability of using active types of movement (walking and cycling or riding a scooter).

Assessing the impact of the remaining buyer's socio-economic characteristics on the change in probability of using other modes of transportation, in relation to the use of private transport, is practical to be carried out only for the bicycle/scooter mode (for the "public transport" and "walking" modes, the value of p > 0.10). Residents of smaller settlements are more likely to use a bicycle/scooter. However, the probability of using this mode of transportation will decrease compared to the probability of using private transport with the increase in the age of buyers and the increase in the number of people in the household.

4.3 Shopping frequency model attributes and parameters

A binomial logit model with two choice parameters has been used to estimate the frequency of food purchases:

- several times per week (1),
- once a week or less (2).

To estimate the frequency of purchases of non-food products, a multinomial logit model with four choice parameters has been used:

- several times per week (1),
- once a week (2),
- several times per month (3),
- once a month or less (4).

Based on the initial modelling results, the attributes that have a statistically significant impact on the frequency of purchases were determined.

The systematic utility of frequency of grocery purchases is expressed as a linear combination of such attributes:

$$V_{fr}^{food} = \beta_{gen} \cdot attr_{gen} + \beta_{in} \cdot attr_{in} + asa\,, \quad (4)$$

where: $attr_{gen}$ - gender: 1 - male, 2 - female,
$attr_{in}$ - average monthly income level of a household: from 1 to 6.

The probability of grocery purchase frequency of once a week or less:

$$p_{fr2}^{food} = 1/\left(1 + \exp(-V_2^{food})\right). \quad (5)$$

The systematic utility of frequency of non-food purchases is expressed as a linear combination of such attributes:

$$V_{fr}^{non-food} = \beta_{age} \cdot attr_{age} + \beta_{gen} \cdot attr_{gen} + \\ + \beta_{car} \cdot attr_{car} + \beta_{city} \cdot attr_{city} + asa, \quad (6)$$

where: $attr_{age}$ - age of customer,
$attr_{car}$ - owning a car: 1 - yes, 0 - no,
$attr_{city}$ - settlement size: 1 - big city, 2 - medium and small cities, 3 - villages.

The parameters of the binomial model for the frequency of purchasing groceries are presented in Table 8 (Nagelkerke's $R^2 = 0.16$, Count $R^2 = 0.65$).

Values of grocery shopping frequency model parameters are presented in Table 9.

The probability of grocery shopping several times a week increases as the average monthly income level of the household goes up. Women are also more likely to shop for groceries more often than men.

The parameters of the multinomial model of the purchasing frequency of non-food products are presented in Table 10 (Nagelkerke's $R^2 = 0.11$, Count $R^2 = 0.53$)

Table 8 *Goodness of fit statistics*

Statistic	Chi-square	Pr > Chi²
-2 Log(Likelihood)	15.807	0.000
Score	15.493	0.000
Wald	14.876	0.001
Hosmer-Lemeshow Statistic	65.062	<0.0001

Table 9 *Model parameters (reference modality - purchase`s frequency several times per week)*

Coefficient of attribute	Tolerance	Value	p (Pr > Chi²)
βgen	0.995	-0.605	0.010
βincome	0.995	-0.201	0.002
asa		1.701	0.000

Table 10 *Goodness of fit statistics*

Statistic	Chi-square	Pr > Chi²
-2 Log(Likelihood)	33.667	0.001
Score	33.003	0.001
Wald	30.457	0.002

Table 11 *Model parameters (reference modality - purchase`s frequency several times per week)*

Coefficient of attribute	Tolerance	Once a week		Several times per month		Once a month or less	
		Value	p (Pr > Chi²)	Value	p (Pr > Chi²)	Value	p (Pr > Chi²)
βage	0.962	0.020	0.215	0.024‡	0.143	0.044	0.004‡
βgen	0.970	0.114	0.729	0.649	0.057‡	0.210	0.535
βcar	0.974	-0.761	0.037‡	-0.984	0.007‡	-1.173	0.001‡
βcity	0.987	-0.291	0.056‡	-0.318	0.043‡	-0.240	0.004‡
asa		0.438	0.552	-0.345	0.651	-0.225	0.762

‡ - the value of p < 0.10; the most significant parameters

The values of the parameters of the non-food shopping frequency model are provided in Table 11.

As the age of the respondent increases, the frequency of non-food purchases decreases (the probability of making purchases of non-food products with a frequency of "once a month or less" increases compared to the probability of making such purchases with a frequency of "several times a week"). Women are more likely than men to make such purchases with a frequency of "several times per month" rather than "several times per week". Owning a car and living in a smaller settlement increases the frequency of non-food purchases.

4.4 Demand model of purchase

Based on Russo and Comi [36], the number of shopping trips generated by the transport area O can be determined by the equation:

$$N^{O}_{shopping} = N^{O}_{res} \cdot p_{shopping}\,, \tag{7}$$

where: N^{O}_{res} - the number of residents in the transport area of departure O,
$p_{shopping}$ - the probability of making a purchase.

The number of trips in the transport system caused by the need to make a purchase will be:

$$N^{O}_{\mathrm{Pr}T} = N^{O}_{shopping} \cdot p^{shopping}_{\mathrm{Pr}T}\,, \tag{8}$$

$$N^{O}_{PuT} = N^{O}_{shopping} \cdot p^{shopping}_{PuT} \tag{9}$$

where: $N^{O}_{\mathrm{Pr}T}$ - the number of movements with the purpose of purchasing within the transport area of departure *O*, made by private transport,
N^{O}_{PuT} - the number of movements with the purpose of purchasing within the transport area of departure *O*, made by public transport,
$p^{shopping}_{\mathrm{Pr}T}$ - the probability of choosing private transport as a mode of transportation to make a purchase,
$p^{shopping}_{\mathrm{Pr}T}$ - the probability of choosing public transport as a mode of transportation to make a purchase.

The overall probability of purchasing depends on the frequency of purchases of a certain product type.

For groceries:

$$p_{shopping} = p_{fr(1)} \cdot \overline{p_{fr(2)}} + \overline{p_{fr(1)}} \cdot p_{fr(2)}\,. \tag{10}$$

For non-food goods:

$$\begin{aligned} p_{shopping} = {} & p_{fr(1)} \cdot \overline{p_{fr(2)}} \cdot \overline{p_{fr(3)}} \cdot \overline{p_{fr(4)}} + \overline{p_{fr(1)}} \cdot \\ & \cdot p_{fr(2)} \cdot \overline{p_{fr(3)}} \cdot \overline{p_{fr(4)}} + \overline{p_{fr(1)}} \cdot \overline{p_{fr(2)}} \cdot p_{fr(3)} \cdot \\ & \cdot \overline{p_{fr(4)}} + \overline{p_{fr(1)}} \cdot \overline{p_{fr(2)}} \cdot \overline{p_{fr(3)}} \cdot p_{fr(4)}, \end{aligned} \tag{11}$$

where: $p_{fr(1)}, p_{fr(2)}, p_{fr(3)}, p_{fr(4)}$ - the probability of making a purchase with a certain frequency (see section 4.3),
$\overline{p_{fr(i)}} = 1 - p_{fr(i)}$ - the probability that an individual will not make a purchase with a certain frequency.

5 Discussion and conclusions

The purpose of the conducted research is to determine the purchasing behavior of the population under the long-term conditions of increased risk. Data collection for the study was carried out by surveying the residents of the rear regions of Ukraine under martial law.

According to survey results, 92% of respondents purchase at least once a week. This frequency of making purchases is slightly higher than the data for other countries and regions: according to Statista, these figures range from 75% to 87%. However, the obtained results are consistent with the research of Larson and Shin [37] on the purchasing behavior of the population

during natural disasters. People may purchase more often out of fear of shortages or anxiety about rising prices (and the desire to stock up) and for a hedonistic purpose.

According to the studies conducted, in general, the frequency of making purchases is influenced by socio-economic characteristics such as age, gender, income level, and ownership of a car. The frequency of grocery purchases is affected by fewer factors, which is expected since these are products of daily consumption and are needed by all population categories.

The frequency of purchasing groceries is more significant for women than for men, which is consistent with many other studies [10, 13, 29]. However, men are more likely to purchase non-food items.

Having a higher income also increases the frequency of purchasing groceries, although the effect of gender is more pronounced. The results for the impact of income differ from some of the other studies where the dependency is reversed [10, 27, 29]. Shi et al. [10] explained the decrease in shopping frequency of people with higher income levels by the fact that they can drive to the mall and buy more goods in one trip. However, according to our research, most grocery purchases are made at stores within walking distance of one's home, and driving to the mall is less likely than even online shopping. A possible explanation could be the reluctance to go shopping relatively far from home due to the risk of an air raid alarm (and therefore closing of the store), which would obviously increase the time spent shopping (among other inconveniences and dangers). Therefore, the population prefers to make more frequent purchases of smaller quantities of goods closer to home.

The frequency of purchasing non-food products also depends on the settlement size and having a personal car. All the other conditions being equal, the frequency of purchases of non-food goods increases with a decrease in the settlement size. At the same time, the actual probability of such a purchase several times a week is higher for individuals who have a personal car (compared to those who do not own a car), and this difference is more significant for villages. The possible explanation would be a smaller selection of non-food goods in village stores, thus the need to travel to another settlement for them, so people who own a car make such purchases more often, as they are more mobile.

An increase in age has little effect on the probability of making purchases of non-food products with the frequency of "Once a week" and "Several times per month". Instead, it decreases the probability of purchases with the frequency of "several times per week" and increases the probability of purchases with the frequency of "Once a month or less".

Owning a car has the greatest impact on the choice of the mode of transportation for shopping, and, quite expectedly, this parameter significantly increases the probability of choosing the private transport mode. It is interesting to note that the absence of a personal car does not significantly affect the probability of shopping on foot but significantly increases the probability of using the bicycle/scooter transportation mode. The second most impactful parameter is professional status. Moreover, this parameter has very little influence on the probability of using a personal car and bicycle/scooter transportation mode. However, students are more likely to travel on foot, while the working population is more likely to use the public transport.

As the settlement size decreases, the probability of using the bicycle/scooter transportation mode increases, but the probability of moving on foot decreases (perhaps, due to the increase of distance to the store).

The likelihood of using a personal car for shopping trips increases as the income level goes up. In general, this trend is also observed in other studies [26-27]. The probability of using a non-motorized type of movement also increases with the income level but is inverted for the probability of using public transport.

An increase in purchase size has a negative impact on the probability of walking and increases the probability of using private transportation.

It is worth highlighting the high level of online buyers - in general, 92% of respondents made an online purchase at least once during the last year. According to Eurostat data for 2023 [38], among European countries only the Netherlands (92%) and Norway (91%) had such a high share of online buyers (data for Ukraine is not available in the report). Conditions of war and martial law, such as:

- a significant proportion of IDPs do not know the surroundings well enough and prefer to shop online,
- restrictions and unpredictability in the working hours of stores due to air raid alarms,
- lack of electricity and curfews,
- lack of desired brands in physical stores due to issues in the supply chain,
- the possibility of a lower price of purchase, which can be an important factor under the conditions of deterioration of the population's financial situation,

as well as other conditions, can have an impact on the high value of this parameter, although additional research is required to confirm this hypothesis and determine the degree of influence of each of the listed factors. It is also interesting to note that the residents of villages make online purchases of groceries more often compared to the residents of cities (it may be related to a much wider range of products in online stores in combination with the efficient work of delivery services in Ukraine - both the national postal operator "Ukrposhta" and private services).

The obtained results can be helpful in developing measures to adjust logistic processes in long-term crisis situations, considering changes in population behavior.

It is worth noting that the study has limitations due to the complexity of data collection and the absence or confidentiality of statistical information during the martial law.

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Conflicts of interest

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

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