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Estimated Probability of Distributing the Proportion of Private Transport Users Visiting the Urban Focal Points

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Abstract – **The article deals with the problem of estimating the proportion of individual transport users visiting the focal points of various functional orientations. The factors and strategies of transport policy influencing the proportion of visitors arriving at the focal points by their private transport are given. Recommendations allowing for the practical application of the research findings in the organization of transportation in the focal points are developed.**

Keywords – private transport; public transport; focal point; proportion of individual transport users; street-and-road network.

I. INTRODUCTION

Currently, about three quarters of the world's population live in cities, the same trend is observed in the Russian Federation. Living in an urban setting implies a high population density varying within the limits of 50-350 people/ha. In this context the most preferred transport is mass transit public transport (PT) that allows meeting the needs for transportation in the city and even the suburbs. However, the growing level of motorization caused by the development of technology and people's well-being offers more convenient ways of driving private or individual transport (IT); they are primarily expressed in higher driving speeds, freedom to choose a route, relatively limited amount of luggage and other advantages as compared with PT. At the same time, IT demands huge resources related both to the traffic capacity of the street-and-road network (SRN) and to the area of short-term storage (parking) places, so identifying the proportion of trips made by using IT is an important scientific and practical task in traffic planning.

II. METHODS AND MATERIALS

The choice of the travel mode (by public (PT) or individual (IT) transport) is very difficult to predict, since the probability of choice depends on a large number of objective and subjective factors. Public transport includes buses, trolleybuses, trams, commuter trains, subway and in some cases cable railways and escalators. In the given research, walking (foot traffic) is included in the category of public transport, since sociological studies of behavior show a high probability of using public transport if it is available even for short distances. The textbook [5] provides data on the probability of foot traffic depending on the purpose of correspondence and distance. The general consistent patterns of these data involve both increased probability of walking for cultural, daily and recreational correspondences as compared with labor ones and reduced probability of foot correspondences with an increase in their distance. If the distance of correspondence is less than 500 m the probability of walking for work purposes is 0.9, for cultural and daily purposes – 0.95, for recreational ones – 0.99. If the distance of correspondence is increased up to 1,500 m the probability of labor correspondences drops to 0.6 and of recreational ones – to 0.85. Thus, it is necessary to take into account the probability of foot correspondences when developing calculated transportation districts and identifying the proportions of correspondences by public and individual transport.

Individual types of transport include cars, bicycles, scooters. Recently, vehicles such as *Segway* and scooters with different engine units including gasoline engines have become rather popular. The distance of transportation by such vehicles is limited; but given that the average transportation distance in major (Moscow) and largest cities does not exceed 15 km [4], and in most cities it is about 4-8 km a significant proportion of trips could fall on these transport types if the average speed is 20 km/h and the appropriate infrastructure is available.

The choice is influenced by the level of motorization in the country and the region, namely, a real opportunity to use a personal car, proximity of PT routes which means a real opportunity to use PT, the trip purpose (labor/cultural/ daily/business), place of living (city/suburb), weather conditions, level of service/comfort of PT (traffic regularity, safety, remoteness of the departure point from the stopping point, remoteness of the stopping point from the point of destination, etc.), cost estimate of the trip, time spent on transportation, time of the day, health state, and even the person's mood. The probability of using individual transport is often increased when it is necessary to perform so-called mixed correspondences (visit several places with different purposes); in this case the use of IT can be more convenient for obvious reasons.

The analysis both of the data given on the websites of the transport departments of large cities in Europe, the USA, etc. [1–3], and of the studies in the field of traffic demand [8–10] shows that the transport policy implemented in the country can significantly influence the level of motorization and,

consequently, the distribution of the proportions of using individual and public transport. Of course, the results cannot be seen in 2–3 or even 5 years, but the experience of European cities shows that the decisions taken give results in 7–15 years. In general, the transport policy can be divided into three conventional directions: 1) severe restrictions on using IT; 2) providing incentives for PT trips; 3) providing incentives for using IT. If the first direction is chosen (Hong Kong, Singapore), the average motorization does not exceed 100–120 vehicles/1,000 residents. It becomes possible due to high taxes and custom duties, high cost of parking, fuel, vehicle maintenance, etc. It should be noted that the first direction largely limits the mobility of population, artificially reduces the standard of living and inhibits the development of territories. The second direction is less radical in general, but in some cases it is more repressive, for example, in relation to the central zones of cities where parking costs are very high (congestion charge for driving in the city center: Paris, London, New York, etc.). The main distinction of this direction is the following conceptual approach: the closer the city center is, the more expensive IT using is. It should be noted that to make the transportation of suburban residents convenient, the authorities try to develop all possible ways of a quick change of IT to PT, for example, intercepting parking lots P+R and extensive PT networks. With this approach the average level of motorization is fixed at the level of 340–360 vehicles/1,000 residents. The third direction is usually associated with short-sighted lobbying of laws aimed at developing a powerful market for the consumption of vehicles as a product and for the corresponding service for them, including road construction. A number of US cities (San Francisco, Los Angeles, Detroit, and others) chose this approach. The main argument in favor of using IT is living in districts with low-rise buildings which does not allow organizing cost-effective PT routes. Within this context the average level of motorization can reach 600-650 vehicles/1,000 residents.

Despite such a variety of factors influencing the probability of choosing a transportation mode and, consequently, the proportion of IT correspondences, there are some consistent patterns. First of all, it is transportation in suburban areas: there are a lot of settlements, individual housing construction (IHC), villages, gardening non-profit partnerships (GNPP); people living in them use IT more often than people in cities despite the PT communication. People often go somewhere for cultural and daily purposes by IT, whereas, trips having business purposes as well as trips to catering places (cafes, restaurants) with an extensive network of route vehicles are more often made by PT. Table 1 shows the proportions of IT trips to different types of focal points (FP): *IHC, settlements, villages, GNPP and voluntary non-profit partnerships (VNPP); **only high-rise buildings

The table shows that the largest share of visitors using IT is observed in residential zones, industrial zones and service centres. Currently, the car is stored directly near the places of living in the vast majority of cases, and there is no significant difference between high-rise urban buildings (IT proportion of 0.619) and individual housing construction, settlements, GNPP, VNPP (IT proportion of 0.804).

TABLE I. PROPORTION OF VISITORS USING IT

FP Name	Proportion of Visitors Using IT
Governmental institutions	0.317
Offices	0.367
Retail trading	0.438
Education	0.447
Medical centres	0.45
Recreation and entertainment zones	0.567
Ports and transport terminals	0.631
Service centres	0.633
Industrial zones	0.726
Residential zones	0.619**/ 0.736/0.804*

The current situation is conditioned by the lack of government regulation of IT use, decreased popularity of PT and a number of macroeconomic factors, for example, by the insurance development, the cost of which often becomes equal to or a bit lower than the cost of storing a car on specialized guarded parking lots. Besides, this fact is proved true by the reduced cost of garages that have been used primarily as storerooms for the last 5–7 years. Industrial zones can arguably be the areas of high demand for the use of individual transport because there is no opportunity to use PT or it does not go regularly. Service centres primarily include the services for individual transport (car wash, service station, etc.), so the percentage of IT users visiting these FPs is high. In the context of the distribution of correspondences by IT between target correspondences (labor, cultural and daily), no differences were identified.

IT is used for education purposes to a lesser extent; it is conditioned by the fact that it involves certain social groups of population (schoolchildren, students), in fact, trips to higher educational institutions, technical schools and colleges should be considered as labor ones. It should be mentioned that a lot of students live very close to the university (technical school) in the dormitory/campus. Governmental institutions can be regarded as office buildings, as they are primarily located in the city center. It is always easier to get to the city center by PT, as it is difficult to park a car, if there is no departmental parking lot, so parking takes a lot of time and during the winter period additional heating is needed, which can worsen the ecological situation.

It is worth noting that the average proportion of IT use for all types of correspondence was 0.512, on weekdays it was 0.565, so there is no significant difference between using individual transport on weekdays and weekends. Besides, the conducted studies allow determining the proportion of IT usage in summer (May-October inclusive) and winter (November-April inclusive) periods, which is 0.618 and 0.468, respectively. It should be mentioned that the data on the decrease in the number of cars in winter given in the Russian scientific literature are not confirmed in the current situation; moreover, the opposite dynamics was determined with the difference of 32 %. According to the authors, this trend can be explained, first of all, by the changed culture of using IT, as, nowadays, IT maintenance becomes quite easy, cars are not stored in garages

or special parking lots but in high-rise and individual building yards, technical innovations allow the owners to warm up their cars remotely, using winter tires and reagents increases driving safety. In general, a modern car is a very convenient and low-maintenance means of transportation, that is why it is increasingly used year-round. At the same time, the decline in the proportion of people arriving at focal points by IT in summer is conditioned by the fact that the working-age population using the greatest part of the vehicles go on holidays to the country, summer cottages, recreation centers, etc.

The dependence of IT use distribution was determined in quantitative terms when analyzing the data on the average parking time in the integrated groups of FPs. For example, the proportion of IT use in the group *Service Centres* shows a dependence reflecting a decrease in the number of IT users against an increase in parking time (Fig. 1); however, when visiting medical centres, the share of IT users grows depending on the time of parking. In general, the correlation between the proportion of correspondence by IT and the time of parking is rather low.

In general, the dependence of the proportion of IT correspondences on the remoteness from the main street should be linear, as the public transport network coincides with the network of main streets. Therefore, if the distance to the main road increases the proportion of IT users should also increase, however, most of the dependencies are quadratic ones. Multifunctional shopping centers, as a rule, are located at some distance from the main streets, as they pretend having their separate territory, but the task of any shopping center is to be accessible to visitors, since it influences the number of visitors and revenue. It is the reason why the dependence of remoteness from the main road is quadratic in this subgroup. Retail trading (grocery stores) also presents a quadratic dependence, but in this case the dependence is inverse: if the remoteness increases, the proportion of IT use also increases, since parking on main roads is either forbidden or rather inconvenient. The growth of IT users proportion continues up to a certain peak, which reflects a walking distance of 400–500 meters, and in some cases, it is related to the visibility distance of a store. Afterwards, there is a decrease in the proportion of visitors using IT, as, in the vast majority of cases, if the store is at a considerable distance from the main road it is visited mainly by residents of this remote district (place) and, naturally, it is not necessary to use IT for visiting the store.

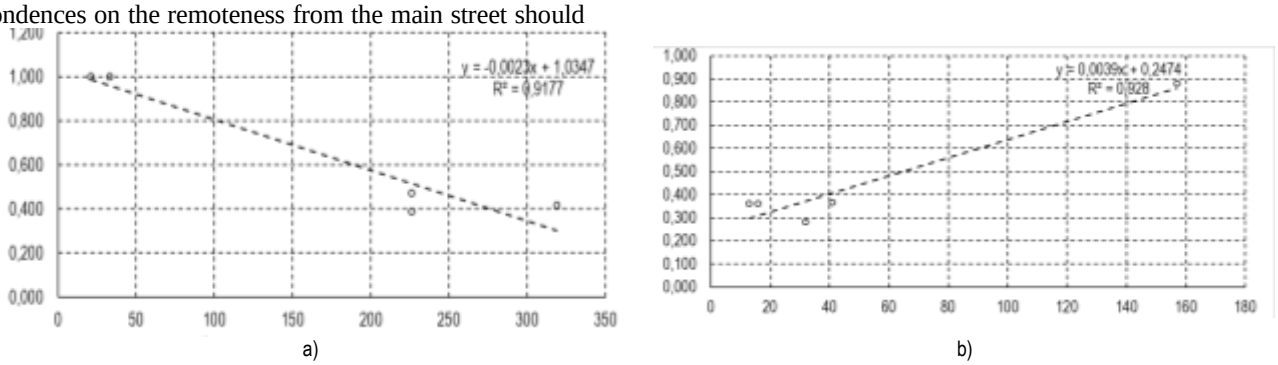

Fig. 1. Dependence of IT Correspondences Proportion on Time of Parking: a) Service Centres; b) Medical Centres

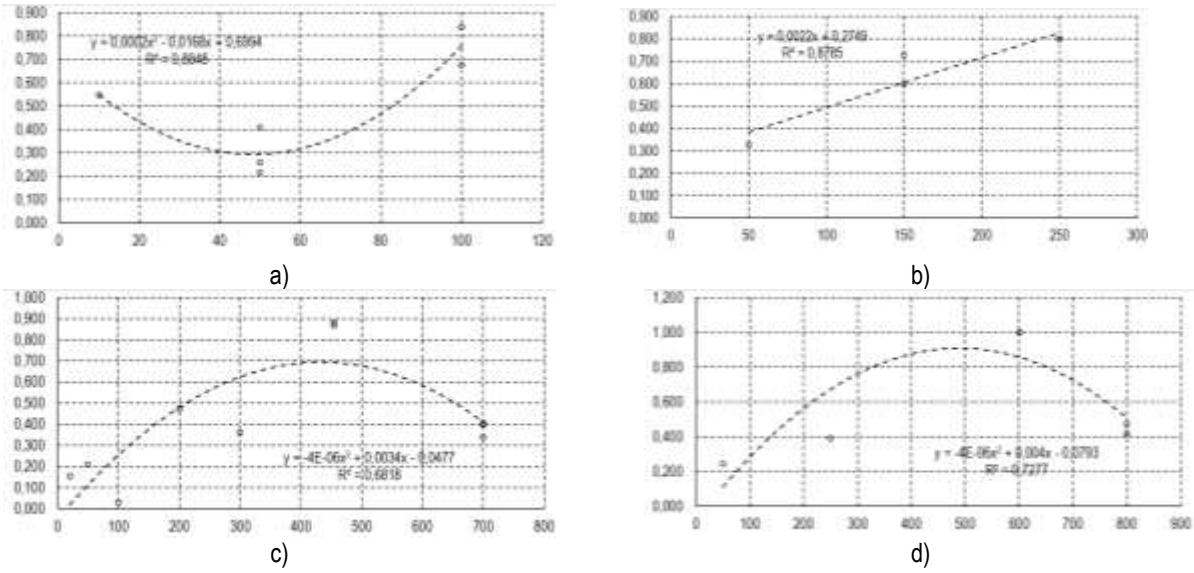

Fig. 2. Dependence of IT Correspondences Proportion on the Remoteness from the Main Road: a) Multifunctional Shopping Centres; b) Retail Trading (Alcoholic Beverages Stores); c) Retail Trading (Grocery Stores); d) Service Centres

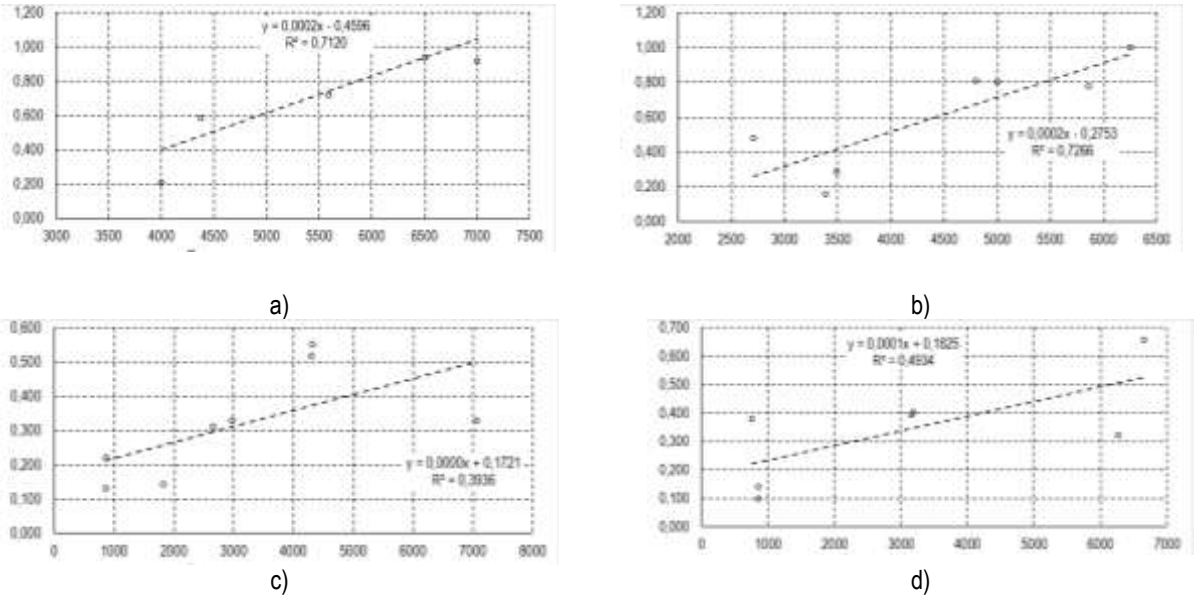

Fig. 3. Dependence of IT Correspondences Proportion on the Distance from the City Centre: a) Industrial Zones; b) Recreation and Entertainment Zones on Weekends; c) Governmental Institutions; d) Offices

The assessment of the impact of remoteness from the city center (Fig. 3) shows the linear dependence of the proportion of visitors using IT on the remoteness from the city center. Particularly, such dependence was determined in industrial zones (R^2=0.71), recreation and entertainment zones (R^2=0.72); the maximum convergence was provided by the data received on weekends. Such a consistent pattern can be explained by the desire to use IT for cultural and daily purposes exclusively on weekends. The remoteness from the city center influences governmental institutions and offices to a lesser extent (R^2=0.39–0.49).

III. Findings

Dependences of the proportion of visitors using IT on the distance from the city center in the groups *Residential Zones* and *Retail Trade* could not be identified. Table 2 shows the coefficients of multiple determination representing the relations between the proportion of visitors using IT and the factors considered.

Table 2 and Figures 1–3 show that the time of parking has almost no impact on the proportion of visitors using IT except for medical institutions and service centres. According to the authors, this finding is conditioned by the specific factors of visiting these objects. Primarily, visitors cannot predict the duration of their visits to these objects, and, consequently, the duration of parking, this fact may lead to the necessity of using a personal car – it can be considered as a place where they can wait for receiving the required service. The impact of the remoteness from the main street is clearly seen in relation to retail trading, as well as medical centres and service centres. In general, this factor is a quadratic dependence reflecting the optimal remoteness from the main road. The influence of the distance from the city center is linear and mainly manifests itself in industrial zones, recreation and entertainment zones (especially on weekends) and offices. It is noteworthy that this factor has little influence on residential zones, even if IHC, GNPP, VNPP are considered separately.

Table 2. Multiple Determination Coefficients of Dependence of the Proportion of Visitors Using IT

Type of FP	Time of Parking, min.		Remoteness from the Main Road, m.		Distance from the City Centre, m.	
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
Industrial zones	0.06	-	0.23	-	0.71	-
Residential zones	0.056	-	0.107	-	0.207	-
Recreation and entertainment zones	0.05	0.06	0.05	0.06	0.34	0.88
Governmental institutions	0.008	-	0.022	-	0.35	-
Medical centres	0.92	-	0.98	-	0.58	-
Offices	0.009	-	0.0009	-	0.49	-
Grocery stores	0.21	0.04	0.96	0.4	0.33	-
Multifunctional shopping centres	0.61	-	0.88		0.03	0.04
Service centres	0.93	-	0.93	-	-	-
Average	0.34	0.05	0.50	0.23	0.40	0.46

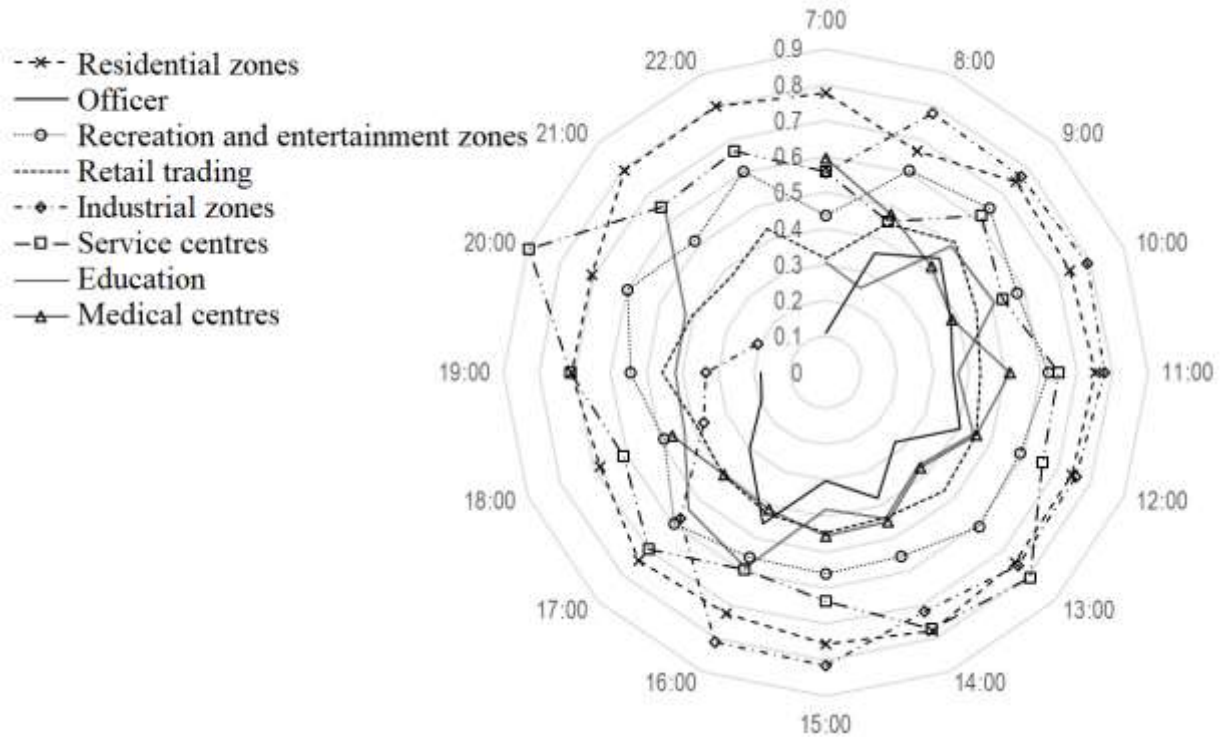

Fig. 4. Dependence of the Proportion of Visitors Using IT on the Time of Day

The proportion of IT use can often differ not only by day of the week or season of the year, but also by the time of day. For example, the largest proportion of people visiting ports and transport terminals, industrial zones, offices by IT will be observed at 4 pm, while for residential zones, education and service centres the peak will be seen in the evening hours – 8–10 pm (Fig. 4).

The radar chart allows not only representing the numerical value of the proportion of visitors using IT visibly, but it also gives the possibility to compare the data by the time of day and by the type of FP. Fig. 4 shows that FPs with a smaller proportion of visitors using IT are closer to the center of the chart, whereas FPs with a greater proportion of IT users are closer to the outer borders.

IV. Conclusion

The conducted studies were aimed at determining factors influencing the probability of choosing a mode of transportation. They show that IT is the most popular transportation means when visiting recreation and entertainment zones, transport terminals, service centres, industrial zones and residential zones, especially in suburban areas. First of all, this result is conditioned by lack or bad organization of PT. In addition, such factors as remoteness from the main road and distance from the city center show a high correlation with the number of visitors using IT in several FPs, for example, the longer is the time of parking near multifunctional shopping centers, the higher is the probability of using IT. It should also be noted that the proportion of visitors using IT remains almost the same during the day within one type of FP. The given data on the distribution of visitors using IT should be taken into account in transport planning and in estimating the impact of local FPs on street-and-road network.

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