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APPLICATION OF A LOGIT MODEL TO IDENTIFY SOCIO-DEMOGRAPHIC FACTORS INFLUENCING THE CHOICE OF PUBLIC TRANSPORT FOR DAILY TRIPS – A CASE STUDY BASED ON THE EXAMPLE OF THE GÓRNOŚLĄSKA-ZAGŁĘBIOWSKA METROPOLIS (POLAND)

Summary. The attractiveness of an offer is the main factor in determining the demand for public transport services, which goes beyond just the transportation itself and includes various accompanying aspects. Before starting their journey, many people confront the dilemma of choosing a mode of transportation. Often, this choice depends on individual habits. Individuals who possess a passenger vehicle cannot justify the advisability of using it instead of bike or public transportation. The primary objective of the present article was to determine the factors that impact the utilization of public transportation services while traveling. The research used data from surveys conducted among the inhabitants of the Górnośląska-Zagłębiowska Metropolis. During the modeling process, the authors used logit models, which have been used in different countries globally to show the behavior of public transport users, as shown in the literature review. However, the factors that impact the decision to use public transportation by the residents of the Górnośląsko-Zagłębiowska Metropolis remain unexamined. The current results suggest that the choice of a hypothetical travel scenario is mainly influenced by age, education, and employment status. However, no correlation with the gender of potential public transport users was found. Other variables not considered in this study may also impact public transport usage. Nevertheless, the findings lay the groundwork for more extensive, in-depth analyses incorporating a broader range of independent variables that could influence public transport use. The research results, when combined with the application of mobility management tools, could serve as a means to better shape the transport offerings. By enhancing the attractiveness of public transport, ticket revenue would likely increase, leading to an improved financial situation for the communes within the Górnośląska-Zagłębiowska Metropolis. This would also align with the principles of sustainable transport development policy.

1. INTRODUCTION

Currently, in urban settings, there is an issue with the over-reliance on private cars for transportation. The transportation industry accounts for a proportion of total global CO₂ emissions from fuel

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combustion, with road vehicles causing the majority of these emissions. The growing number of cars on Poland's streets is leading to significant traffic issues. The problem is particularly acute in city centers, where heavy traffic jams cause a significant loss of time for people traveling. Another negative effect of increasing congestion is the increase in noise and fuel consumption. The vast majority of journeys are made by car. Decreasing traffic jams in urban areas is possible by shifting the transportation modal split towards more eco-friendly modes. Switching from using a car to taking a bus or tram can decrease the amount of vehicles present on the road.

Recent transport policies and trends in transport research suggest that there could be a rise in demand for improved regional public transport services, as they encourage walking, cycling, and public transport over using cars. Policies promoting active living and travel are aimed at older individuals, children, young people, the average working population, and workplace activities. Sedentary lifestyles affect all generations, and regional public transport services that use walking and cycling as first- and last-mile solutions may play a more important role in the future. However, it should be emphasized that the choice of transport mode depends on many factors that are often difficult to define. Often, this choice depends on individual habits and preferences. People who own a car cannot justify using it instead of a bicycle or public transport.

The proper functioning of cities requires the fulfillment of a basic condition, which is the creation of an efficient communication system. The transport system influences the development of all aspects of life and should meet the expectations of residents. Residents of every city want to reach their destinations directly and as quickly as possible. The demand for public transportation is influenced by how appealing the service is and is not limited to the transportation itself but also includes various other aspects of the service offered. When preparing for a trip, many individuals struggle with deciding on the most suitable form of transportation. Passengers frequently evaluate various transportation options when deciding, taking into account factors like travel duration, fare cost, and comfort.

The process of making decisions frequently takes up a lot of time. To select the best choice, a traveler must evaluate the schedules of the transportation options being considered, compare fares, and confirm the availability of a specific mode of transport. Nevertheless, the ultimate decision varies from person to person based on the passenger's requirements and past experiences. Knowledge about transport behavior is essential in the practice of shaping sustainable transport development in cities. Without it, it would be impossible to enhance the appeal and competitiveness of environmental transport services, such as public transportation, compared to personal vehicle use. Therefore, the logical planning of transportation services needs to be based on the reasons for people's transportation choices and the expectations of service recipients. Ensuring that the improvements in public transport services align with the expectations of both current and potential users is crucial. Hence, it is essential for transportation companies to regularly carry out customer satisfaction surveys, which help in developing the best possible service.

The Górnośląska-Zagłębiowska Metropolis is a metropolitan association located in the Silesian Voivodeship. It was established based on the Act of March 9, 2017, on metropolitan unions and brings together 41 communes of the Silesian Voivodeship. This metropolis focuses on spatial, social, and economic integrity and cohesion in order to ensure an appropriate level of quality of life for its residents. The metropolitan association performs public functions in:

- spatial planning,
- economic and social progress within the metropolitan region,
- the organization and advancement of public transportation, such as road, rail, and other modes of transport, along with promoting sustainable urban mobility, require careful planning and coordination,
- urban passenger transportation networks,
- the path of national and provincial roads within the metropolitan union region,
- the collaboration between the city and its surrounding area.

The primary objective of the article is to pinpoint the factors that impact the utilization of public transportation services during travel. The paper is divided into four sections. Following the introduction, the second part overviews the pertinent literature within the research area of factors impacting

the selection of public transportation methods for daily commuting. In the third part, the factors influencing the selection of public transportation options for daily commuting are outlined following the display of descriptive data. The logit model was utilized in the modeling procedure, with the structural parameters being determined using data gathered from a survey of the residents of the Górnośląska-Zagłębiowska metropolitan region. The article ends with a recap and final thoughts.

2. LITERATURE REVIEW

The diversity of the transport needs of people using different transport modes has resulted in a significant number of scientific works devoted to these issues, aimed at understanding the determinants influencing choosing a specific mode of transportation in everyday travel. Awareness of these characteristics could enable the division of transport tasks to be managed appropriately and have a positive impact on the evolution of the transportation system following the principles of sustainable transportation development.

In [1], Ethiopian authors developed a logit model. The results showed that traveler characteristics such as age, family size, income, profession, and education level had statistically significant roles in the selection of transportation modes.

Authors from India pointed out that women's travel choices are more environmentally friendly than men's. Highly educated, employed, and middle-aged individuals seem to gravitate towards using more environmentally harmful modes of transportation when traveling often. People with the least amount of wealth and resources tend to be the most environmentally conscious. These conclusions were drawn based on the developed logit model, which was based on interviews with 600 people [2].

The research carried out by authors from Krakow, Poland, revealed that several factors, such as gender, age, car ownership, main daily activity, possession of a driving license, gross monthly income, time spent in current residence, place of daily shopping, sense of belonging to one's neighborhood, quality of social/recreational facilities in the neighborhood, and distance to work, can forecast the selection of commuting and non-commuting modes. Similarly, gender, daily activity, financial reliance on family, entertainment options, quality of social/recreational facilities, independent decision-making for place of residence, number of commutes, time spent in current residence, and road connectivity around the residence are linked to public transport usage. The research employed logit and probit models to analyze the mode choice and frequency of public transportation usage by college students in Krakow, Poland [3].

A logit model was also used in [4]. The results show that although car use is the dominant mode choice in Vorarlberg, socio-demographic variables, including age, gender, population density, income level, and travel motive, are also strongly correlated with mode choice. Furthermore, the mode share by density shows that high-density areas are associated with more cycling and walking.

Research conducted by authors from India [5] demonstrated how factors like gender, age, and having school-age children influence how a person chooses to travel to work. The research indicates that the majority of workers favor using public transportation to commute to their jobs. They are more likely to commute between 8:00 and 10:00 than during other hours. A logit model was used in this research.

Authors from Germany, using a probit model, showed that well-educated people use public transport in urban areas more often [6].

Research conducted by P. Kral, K. Janošková, and T. Klietnik (the Slovakia Republic) [7] showed that age is an important variable influencing the intensity of using suburban bus transport. Gender does not matter, but the higher education levels and incomes of respondents reduced how often they use suburban bus transport. Correlation analysis, Chi-square test, and Fisher's test were used in the study.

In Australia, it has been shown that women have a stronger inclination towards using public transportation than men. Also, compared to other age groups, respondents aged 35–44 showed a greater preference for driving a car. The findings also indicate that older individuals might choose to take public transportation instead of driving in heavy traffic situations, such as during peak hours. The study utilized multinomial logistic regression. [8].

Another study presented models indicating that socio-demographic factors like income, occupation, and gender greatly impact commuters' choice of transportation mode [9].

Researchers from Germany [10] demonstrated that age, household size, net household income, car ownership, and occupation are the key socio-demographic factors influencing the usage of public transportation. A Chi-square test was used to identify variances in factors affecting transport mode choice, while the Kruskal-Wallis H test was used to determine statistical significance.

Other analyses showed that income levels played a significant role in determining the preferred mode of transportation, with people in lower income brackets showing a higher tendency towards using public transportation compared to those in higher income brackets.

Based on the analysis of the literature, it can be inferred that the following factors are the primary factors influencing the selection of public transportation for daily commuting:

- age,
- family size,
- income,
- profession,
- education,
- gender (in selected analyses),
- having offspring.

3. ANALYSIS OF FACTORS DETERMINING THE USE OF PUBLIC TRANSPORT

3.1. Characteristics of Respondents

Figs. 1-4 display the traits of participants separated into regular and occasional users of public transportation in the Górnośląska-Zagłębiowska Metropolis. Most responses were received from women aged 24 and over with a high education level who were still studying or working. In many cases, the proportion of people who use public transport services in certain groups of respondents is at a similar level to the proportion of people who do not use public transport.

Respondents were also asked what encourages them to use public transport services. Respondents had the option of multiple choices. Fig. 5 shows the respondents' answers. The data show that respondents choose to use public transport services because they do not have a car, transport stops are located close to the sources or destinations of their journey, and there are no parking lots at their travel destinations or there is a problem with the occupancy of parking spaces.

Respondents were also asked what discourages them from using public transport services. Respondents were able to choose multiple answers. Fig. 6 presents the respondents' answers. The data show that respondents most often refrain from using public transport services because of delays, high prices, the and low frequency of services.

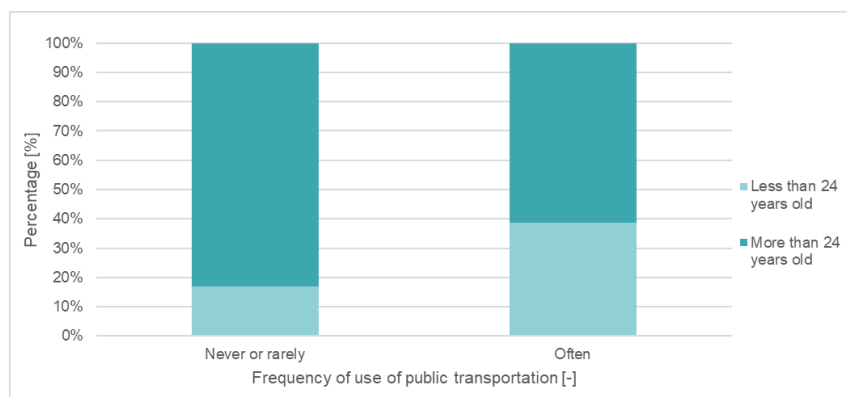


Fig. 1. Attributes of respondents who frequently use and avoid using public transportation in the Górnośląska-Zagłębiowska Metropolis in relation to age

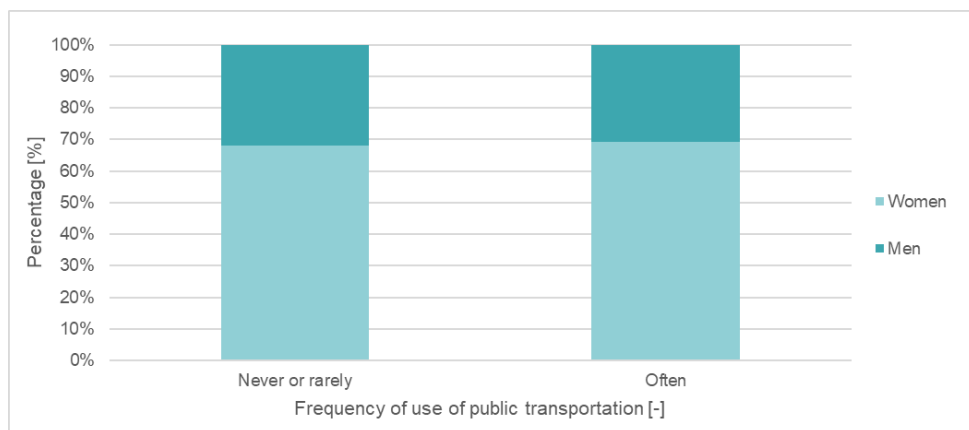


Fig. 2. Attributes of respondents who frequently use and avoid using public transportation in the Górnośląska-Zagłębiowska Metropolis in relation to gender

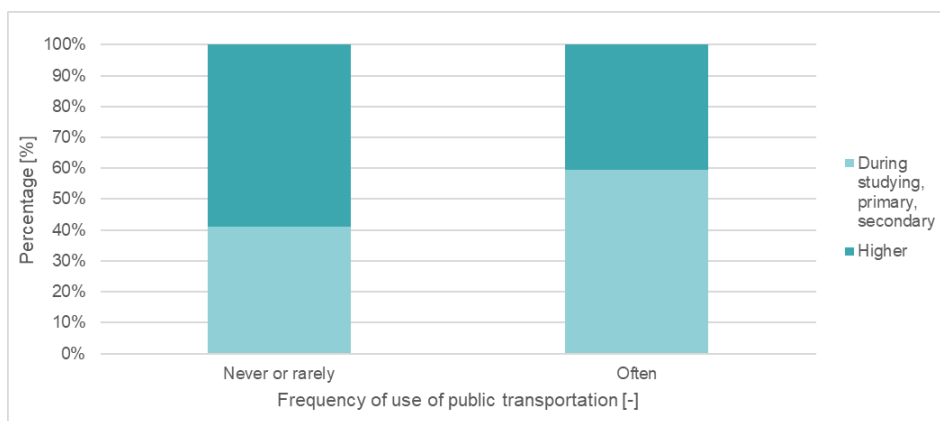


Fig. 3. Attributes of respondents who frequently use and avoid using public transportation in the Górnośląska-Zagłębiowska Metropolis in relation to education

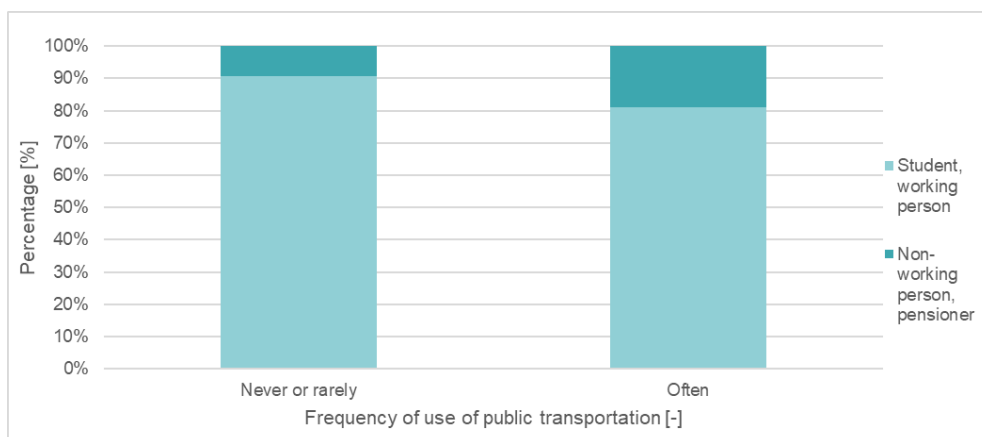


Fig. 4. Attributes of respondents who frequently use and avoid using public transportation in the Górnośląska-Zagłębiowska Metropolis in relation to professional status

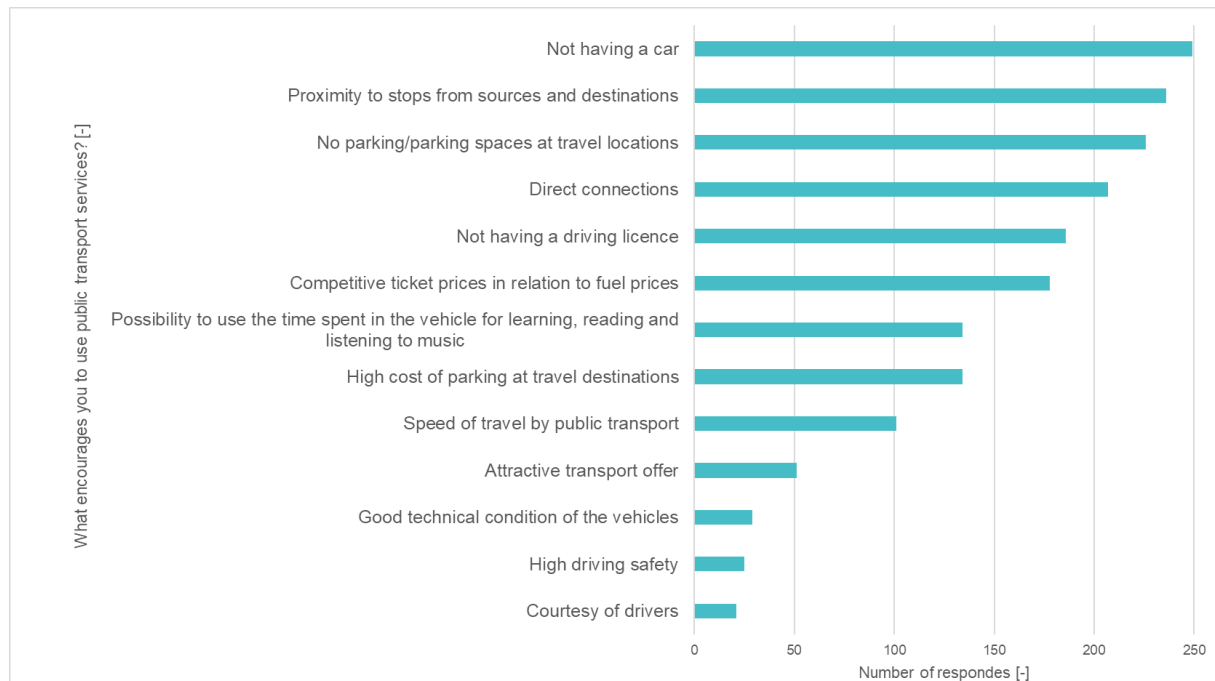


Fig. 5. Reasons encouraging passengers to use public transport

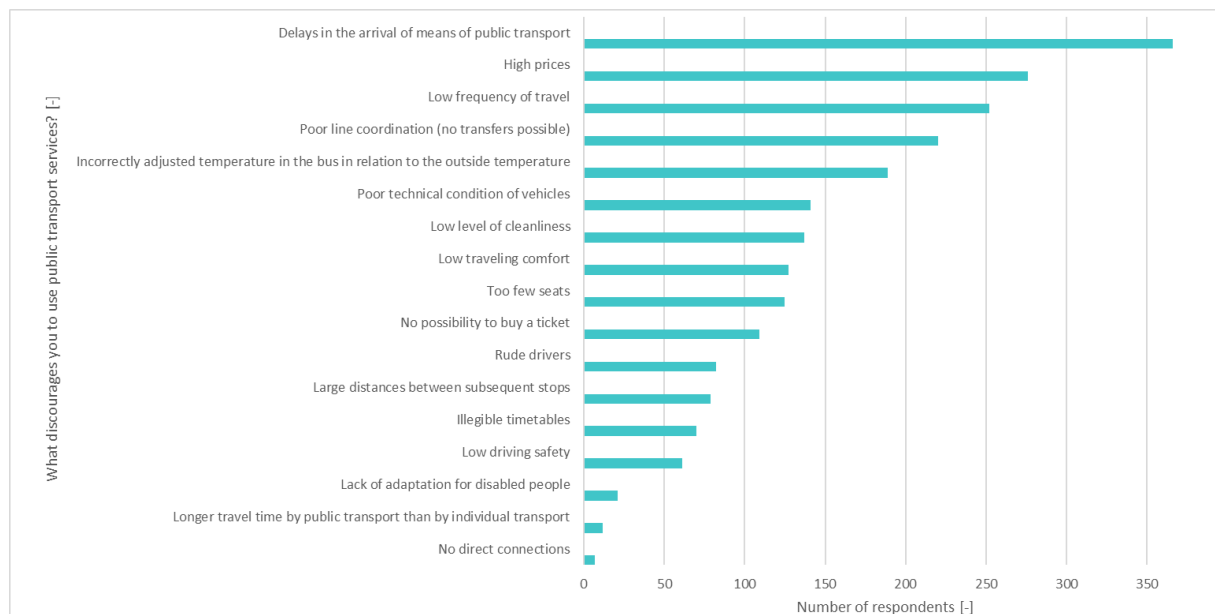


Fig. 6. Reasons discouraging passengers from using public transport

3.2. Binominal logit model

A logit model, which is a form of binomial logistic regression model, was utilized to elucidate the binary qualitative variable Y by considering the exogenous variables X_1, X_2, \dots, X_k (either qualitative or quantitative). A dummy variable is commonly used to represent the dependent variable:

$$Y = \begin{cases} 1 & \text{the event occurred} \\ 0 & \text{the event did not occur} \end{cases} \quad (1)$$

A logit model is a specific instance of the generalized linear model [11]:

$$g(\mu) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k \quad (2)$$

where β_0 is an intercept; $\beta_1, \beta_2, \dots, \beta_k$ are the coefficients of the regression, and g is the link function that determines the connection between the mean of the variable being described $\mu = E(Y|X_1 = x_1, X_2 = x_2, \dots, X_k = x_k)$ with a linear combination of predictors. In the logit model $\mu = p = P(Y = 1|X_1 = x_1, X_2 = x_2, \dots, X_k = x_k)$, and the logit function, which is used for binding, has the following structure:

$$g(p) = \text{logit}(p) = \ln \frac{p}{1-p} \quad (3)$$

The odds ratio is used to describe the ratio of the likelihood of an event happening to the likelihood of it not happening.

The β coefficients of significant qualitative variables in a logistic regression model can be utilized to compute the odds ratio of specific individuals who utilize public transportation services. The odds ratio is given by the following formula:

$$\text{The odds ratio } (x_i) = \exp(\beta_i) \quad (4)$$

3.3. Logit model results

The questionnaire contained questions that enabled the selection of various explanatory variables, which were then utilized in the analysis to assess their influence on the decision to use public transportation during travel. The subsequent variables were considered to determine the likelihood of using public transport:

- AG – age,
- GE – gender,
- ED – education,
- PS – professional status,
- Y – public transport use.

The model took into account the respondents' characteristics (i.e., gender, age, education, and professional status). The form of the model is shown below.

$$\text{logit}(p) = \beta_0 + \beta_1 AG + \beta_2 GE + \beta_3 ED + \beta_4 PS \quad (5)$$

The table lists the independent variables used to assess the utilization of public transportation.

Table 1

Factors chosen to evaluate the utilization of public transportation

No.	Variable [-]	Characteristics	Symbol
1	AG [years]	Less than 24	0
		More than 24	1
2	GE	Female	0
		Male	1
3	ED	During studying, primary, secondary	0
		Higher	1
4	PS	Student, working person	0
		Non-working person, pensioner	1

The analysis results are shown in Table 2.

In the model, most of the coefficients on the independent variables have negative values (except for PS). The respondent's age had the greatest influence on the use of public transportation in the Górnślaska-Zagłębiowska Metropolis. The ED and PS variables also have a considerable influence on the utilization of public transportation. Gender is the least significant factor. Individuals aged 24 and

older, as well as those who have attained a high level of education and are either unemployed or retired, are less inclined than others to utilize public transportation services.

Table 2

Logit model results

Variable [-]	β_i	p -value
AG [years]	-0.955	0.000
GE	-0.085	0.628
ED	-0.353	0.046
PS	0.540	0.033
Constant	1.027	0.000
H.R. (hit ratio) [%]	65,46	

The model used in this study achieved a Hit Ratio (the H.R. ratio) value of 65.46%. This means that these variables can greatly influence the likelihood of utilizing public transportation. Fig. 6 shows the Receiver operating characteristic curve (the ROC curve).

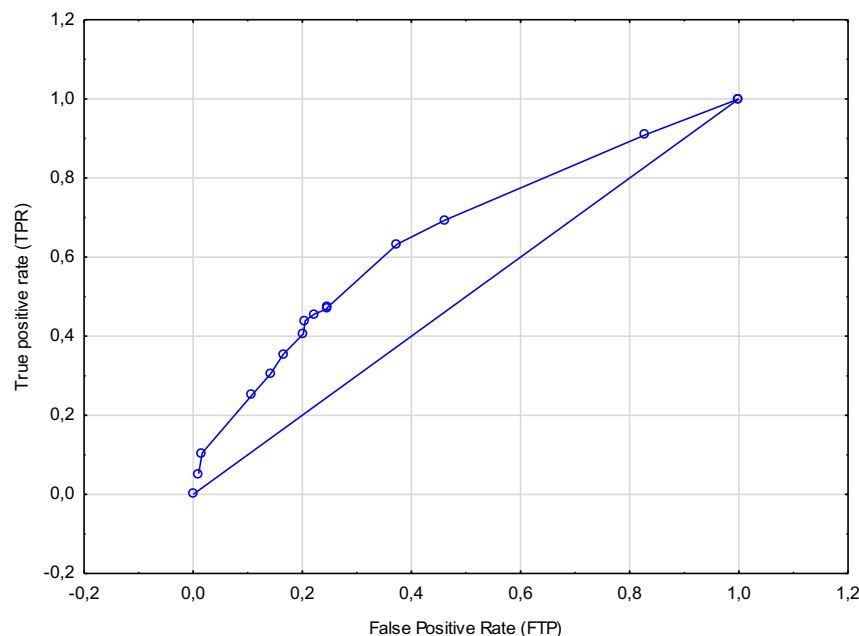


Fig. 7. The ROC curve

The odds ratio expresses how many times more likely people are to use public transport services under various circumstances compared to situations when these circumstances do not occur. Fig. 8 shows the values of the odds ratios for specific independent variables.

The chart shows that the highest odds ratio value is 0.92 (for GE), while the lowest value is 0.38 (for AG).

4. CONCLUSIONS

The primary objective of the article was to pinpoint the factors that affect the utilization of public transportation services. Data from a survey of residents of the Górnośląska-Zagłębiowska metropolitan area were used to estimate the logit model's structural parameters. According to the analysis, the following conclusions can be made:

- the AG variable has the most significant influence on the utilization of public transportation services in the Górnślaska-Zagłębiowska Metropolis.
- the ED and PS variables are also important factors that influence the utilization of public transportation.
- the GE variable holds the least significance.

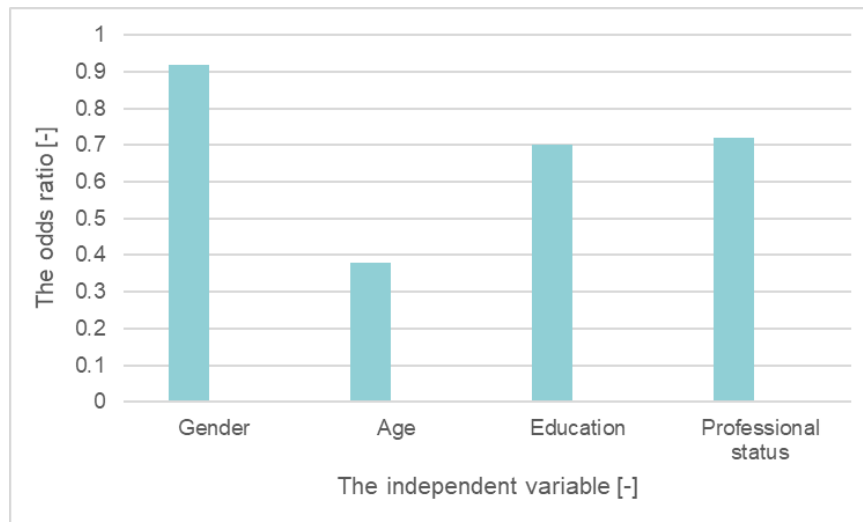


Fig. 8. Odds ratios

Specifically, individuals who are 24 or older, have advanced education, and are unemployed or retired are less inclined than others to utilize public transportation services. This could be because individuals below 24 are typically students and may not possess a driver's license. Thus, they often rely on public transportation to travel. Individuals who are unemployed or have already retired tend not to travel frequently, reducing the probability that they will utilize public transportation services compared to employed individuals. According to the ROC curve analysis, the independent variables considered in the model have a substantial effect on the likelihood of utilizing public transportation.

The same findings were indicated by the odds ratio outcomes, which showed an increased likelihood of using public transportation in different scenarios compared to when these scenarios do not take place. For instance, individuals over 24 years old had an odds ratio of 0.38 for using public transportation, indicating a 62% lower likelihood compared to those under 24. When the person is male, the chance of using public transport services is 0.92. This indicates that males are 8% less inclined to utilize public services compared to females. The likelihood of utilizing public transportation is 0.70 for individuals with higher education, meaning their chances are 30% lower compared to those with secondary education or studying. An unemployed individual, retiree, or pensioner has a 0.72 odds ratio of utilizing public transportation services. This indicates that one's likelihood of using public services is reduced by 38% compared to someone who is studying or working.

The studies conducted by K. Gebeyehu and M. Shete [19] yielded comparable findings. According to their model, family size and income are the most influential factors in the choice of transportation, alongside age, occupation, and education level. The models presented in other studies suggest that user gender significantly influences one's choice of transport mode; this finding is not supported by the other studies cited.

Variations in how various factors influence people's choices of transportation for their daily trips, as described in various articles, may have arisen because the studies were carried out in diverse countries globally. Road users in different locations may exhibit various communication behaviors, and cities have varying levels of road infrastructure and provide a range of public transportation choices. It is worth mentioning that various authors considered varying independent variables in their studies.

The findings provided in the present study will serve as a foundation for additional, comprehensive examinations involving a greater variety of independent variables that could influence the utilization of

public transportation. However, the findings of research conducted alongside the implementation of mobility management tools could help improve available transportation services. For example, the organizer of public transportation could create a special offer for employers. By contributing funds for tickets for public transportation services, employers could motivate their employees to use public transportation rather than personal vehicles. This could also lead to economic advantages for business owners, such as decreased costs for company vehicles and parking spots. Improving the appeal of public transportation in the Górnośląska-Zagłębiowska Metropolis would lead to higher ticket sales revenue, resulting in a better financial situation for the local communes.

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