GENERALIZED ORDERED LOGIT MODEL WITH TESTING ASSUMPTIONS: A CASE STUDY OF USING URBAN LIGHT RAIL IN BURSA

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Resume

Logistic regression has been a widely used prediction technique to analyze categorical variables. However, if the assumptions are violated the results may be biased. The study in this paper applied an analytical technique namely generalized ordered logit model. A case study of using urban light rail under pandemic conditions was applied for the analysis. The results suggested that logistic regression should not be applied before exploring the multicollinearity and applying the test of parallel lines. If the assumptions are violated, generalized ordered logit model should be considered. Regarding the predictive variables, sociodemographic, socioeconomic and travel pattern, related variables were found to have a statistically significant impact on the perception of safety and infrastructure of urban light rail. The outcomes of the study would provide a deeper understanding of developing regression models for categorical variables for future studies.

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1 Introduction

The Covid-19 pandemic has changed urban travel behaviors in many countries [1-2]. The travel distance was reduced by approximately 60% [3]. Not only the need for travel, but the mode choice behavior has changed significantly, as well

. A shift from public transport use to private motor vehicle use, cycling, and walking was observed [4]. Transport authorities claimed that a 95% reduction in public transport use was observed during the peak period of the pandemic [5]. Although there has been a significant decrease in travel distance during the first months of the pandemic, it increased gradually during the post-pandemic period [6]. The study [4] suggested that private motor vehicle use and walking came back to normal levels during the post-pandemic period. However, public transport use could not reach the pre-pandemic level [3]. Due to the remote working option and the discomfort in crowded spaces, a straightforward return to the pre-pandemic status of the public transport use is not achievable [7]. In addition, the lack of emergency readiness in the public transport sector for a pandemic situation is an important reason for decreased ridership [8]. These cause unsustainable transportation modes to be used more than the public transport [9]. Using the public transport should be encouraged to reduce the level of private motor vehicle use [6]. It was suggested [4] that a deeper investigation should be carried out to understand the reason behind the low level of public transport use due to the pandemic effects. Several socio-economic groups of people have experienced travel mode shifts to varying degrees [10-11]. Therefore, this reason should be examined by considering survey-based socio-economic parameters such as gender, age, education, travel pattern, household size, and personal values, such as perceptions of the mobility system [3, 12]. In addition, study [13] explored the long-term impact of a pandemic on travel behavior and it was suggested that safety concerns should be investigated to reduce the significant and permanent influence on public transport users.

The study in this paper aimed to fill this gap by investigating the influence of the social, travel pattern, and perception-related parameters on urban light rail use under pandemic concerns. The objectives of the study are given as follows: i) examining the level of change in travel patterns before and after the pandemic, ii) selecting the most appropriate prediction model by testing the statistical assumptions, iii) developing the model to explore the impacts on participants' perceptions on urban light rail after the pandemic period.

2 Literature review

Depending on the measures taken by the governments to prevent the spread of the pandemic, there has been a change in the public transportation habits of people trying to deal with this situation [14]. During the peak period of the pandemic-related disturbances, the number of passengers using public transportation decreased by 50% to 90% worldwide [15]. Particularly, there were substantial reductions in metro service durations, with up to a 40% decrease in travel times [16]. The decrease in the use of public transport was in correlation with the rising number of Covid-19 cases [17-19]. It is stated that the most important challenge after the Covid-19 pandemic is to re-establish trust in public transportation [20-22]. Travel behavior, sociodemographic and latent characteristics of the road users were found to be significant for the reason of switch from public transport to other modes during the pandemic [23]. In a study [24], focused on the effectiveness of incentives aimed at promoting public transport usage in China after the pandemic, it was found that while there was a minor increase in public transport use, the impact of the incentives remained limited in achieving significant behavioral change. The safety of individual or social transportation needs can be achieved with sustainable transportation systems [25]. To achieve this goal, the factors affecting the perceptions of users regarding transportation safety should be carefully evaluated at the planning stage [26].

As stated in the United Nations Agenda 30, prepared for sustainable development, it is a human right to feel safe in public [20]. The Great Walk of Athens (GWA) has been determined that the use of public transportation has decreased due to the decrease in the desire to share indoor space after the pandemic and the public did not show the expected interest in the GWA project, and the most important reason for this was that the public was not sufficiently included in the planning stage [27]. This outcome supports the emergency of understanding the reason behind the preference change and planning the transportation system including users' perceptions.

Before exploring the applied studies in this research area, it should be noted that the influence of emergencies on public transportation use may not be at the same level in different regions or among different modes or societies [28]. Particularly, metro and bus modes were affected more than other public transportation options. Environmental and economic concerns are also determinants of people's preference for public transportation [14]. For instance, the UK based study found that users in poor neighborhoods return to public transport faster than people living in more affluent areas [29]. In addition, the regional differences can be influential such as the study [30] suggested that a decrease in the use of public transportation was observed in American and European cities at a similar level, while this rate was found to be less in Asian countries.

Concerning this given information in the literature, there have been several studies, which were conducted in different regions to investigate the reasons behind the decrease in using public transport and not returning to its former levels. One of the major reasons for reduced public transport usage was the sociodemographic background of road users. Women and elder road users exhibited higher susceptibility to using public transport during the pandemic situation [31-32]. The effects of the pre- and post-pandemic on public transport users have been investigated in three different Scandinavian cities; Stockholm, Bergen and Oslo [20]. The results suggested that women experienced more stress and had less confidence while using public transportation during the pandemic period. In addition, elderly individuals significantly reduced their use of public transport. This situation was reduced but not fully recovered post pandemic period. This cannot be explained by the negative service level but by the decrease in the number of individuals who prefer public transportation [20]. The study [33] carried out in Lahore, Pakistan indicated that elderly individuals were less likely to use public transport in the absence of necessary precautions, while individuals with lower levels of education exhibited higher usage, highlighting the potential for attitude change through the implementation of sanitation measures and informative activities [34]. The decrease in public transport use occurred among mid-high age users, however, people under the age of 30 had to keep using public transportation because the majority of the young road users did not have access to private vehicles in India [35]. Mostly elder groups tended to switch their travel mode from public transport to private motor vehicles, and this preference has not been recovered yet. The study carried out in Germany suggested that women and those living in the suburbs tended to use private vehicles more during the pandemic period [36]. Total of 19% of the participants, who did not own a car, were tempted to buy a car even though they could live without a car. These results clearly showed that the public transport behavior has been changing among different sociodemographic and socioeconomic groups [37]. Consequently, a permanent modal shift behavior was observed.

In a comprehensive study [38], conducted in

Warsaw, it was found that there was a substantial transition away from traditional public transportation towards individual modes of transportation. Individuals in the high-income group, and those who primarily use motorcycles as their mode of transportation, exhibited a strong preference against using public transportation due to their significant dependency on private means of transportation, regardless of adherence to pandemic safety protocols [39]. The outcomes of the study [40], conducted in Scotland, suggested that the post-pandemic preference for private vehicle usage over public transportation was likely to result in adverse environmental consequences, while the adoption of remote working arrangements and increased bicycle usage was expected to have positive environmental effects. In a survey based comprehensive study [41] conducted in Greece, it was uncovered that the transportation behaviors adopted during the pandemic, specifically walking and cycling, were anticipated to persist among individuals even after its resolution, particularly in the short term. The data obtained from the public transport service providers in Spain was analyzed and it was found that in the post-pandemic "new normal," there has been a notable increase in the use of bicycles as shared transportation and a higher overall traffic density compared to the utilization of public transport [42]. The study [23], conducted in Athens, suggested that self-employed individuals and owners of private cars were less inclined to revert to using public transport after the pandemic. During the two waves of the pandemic in Australia, surveys indicated that the use of public transport was influenced by the adoption of remote work practices, and it was further concluded that government incentives would be a determining factor in shaping public transport behavior [43].

Further studies focused on the road users' perception of public transport use under comprehensive health issues. A survey was conducted online with the participation of 700 people across Sicily island of Italy. It was concluded that policymakers should investigate the psychological and emotional aspects of using the public transport against private motor vehicle mode shift [44]. A survey-based study [45], covering 8 cities in China, suggested that taking temperature measurements in public vehicles can be useful in reducing health concerns caused by Covid-19. Through an examination conducted during the Covid-19 pandemic in Santiago, a comprehensive analysis was performed using 455 valid survey responses obtained from both an online survey conducted on the Qualtrics platform and a face-to-face survey [46]. The data were investigated to assess users' perceptions of mask-wearing and their attitudes toward crowded vehicles. The results indicated a heightened reluctance towards crowded vehicles, even when all occupants were wearing masks, in comparison to the pre-pandemic period [46]. Based on the data obtained from the smart card system used in public transportation, it was revealed that users modified their public transportation routes and opted for destinations where the pandemic-induced isolation policies were not implemented [47]. Through a study [48] tracking 48 users with GPS before and during the pandemic, it was discovered that the key considerations in the selection of transportation mode and route were the avoidance of crowds and travel time. The study [49] emphasized the importance of commissioning bus lines with small crossing distances to alleviate overcrowding concerns during the pandemic and prevent potential inconvenience to passengers who may be skipped at stops. According to a study [50] analyzing data from the local public transportation service provider in Tampere, Finland, it was found that the public transportation usage declined across the country during the pandemic, and specifically in the eastern part of the city, the crowdedness ratio was higher compared to other areas. The survey conducted with the participation of 420 public transport users in Addis Ababa, Ethiopia revealed that approximately one-third of the participants were found to have symptoms indicative of general anxiety disorder related to the pandemic [31]. Another study [51] conducted in India, which examined the factors affecting the choice of public transport mode, revealed that the key consideration for individuals is the capacity of the mode of transport to provide social distancing. In a study [52] addressing policies for managing public transportation systems during the epidemic periods, several measures, including vehicle disinfection and mask usage, were recommended as a part of a transportation emergency response plan to prevent the spread of the epidemic while ensuring continued service to meet the demand. The study [53] conducted in Gdansk, Poland revealed that the Covid-19 pandemic could lead to subjective safety concerns regarding public transport, resulting in a significant proportion (25%) of participants losing confidence in its safety. The survey conducted in Germany with the participation of 918 individuals revealed that users are expected to experience lingering fear of infection related to public transport even after the pandemic [54].

Regarding the information given in the literature, investigating the factors affecting the perception of public transport use emerges to be carried out. The previous studies mainly carried out a survey and aimed to explore the importance of the parameters by applying several analysis methods, such as structural equation modelling [20, 39], exploratory factor analysis [33], binary logistic regression [36], multivariate regression analysis [37], two-parameter probit model [40], Mann Whitney U test [44], multi-group analysis method [45] and multinomial logit model [23]. The analysis in this paper aimed to focus not only on examining the factors, but also on applying a deeper methodology for investigating categorical variables. The following section explains the case study area, data collection and analytical approach of the analysis.

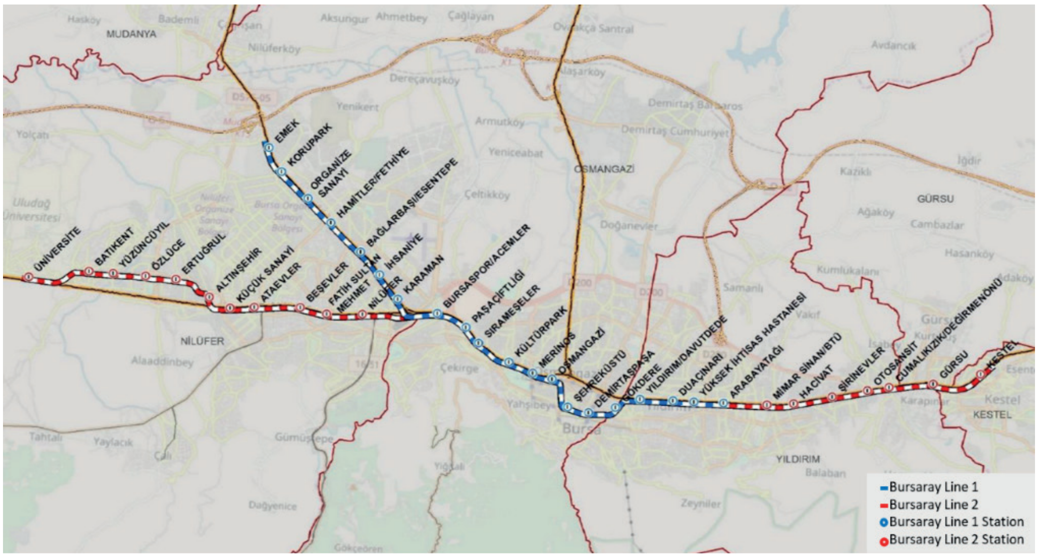

***Figure 1** Bursa urban light rail system*

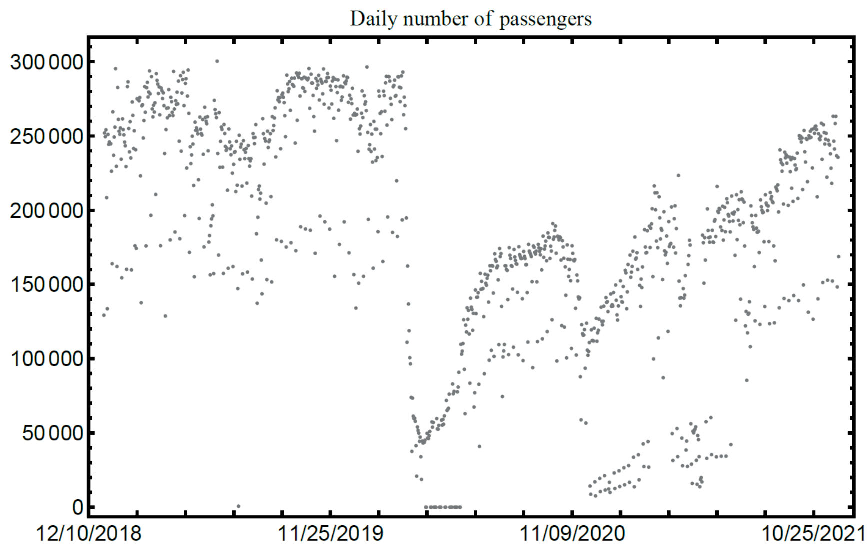

***Figure 2** The daily number of passenger data for Bursaray*

3 Methodology

The case study area in this paper is Bursa city, which has approximately 2 million populations. The south part of the city is narrowed by Uludag mountains and the north part is covered with agricultural lands. Therefore, the city form has a linear structure and the majority of the daily travel movement occurs on the east-west line. Accordingly, the most used public transport mode in the city is the Bursa urban light rail system (i.e., Bursaray) (see Figure 1). Bursaray consists of 2 lines with a total length of 39 km. It has 38 stations and the platforms for each station are 120 m in length. The lines are merged at 13 stations. The system has a 70 km/h operating speed with a fixed blocked signalling system. Average travel times are 34 min and 55 min, for line 1 and line 2, respectively. Station waiting time is between 20 s and 40 s for all platforms. Each train has 4 railcars with 8 doors total. The railcar length, width and height are 28.20 m, 2.65 m, and 3.88 m, respectively. The number of passenger seats located in one railcar is 50.

The transportation network in Bursa primarily relies on the Bursaray rail system, serving as the backbone of public transit in the city. Bursaray is the preferred mode of transportation for many residents, offering linear accessibility to various parts of the city. Notably, the Acemler station serves as a major interchange point, where the rail lines diverge and connect with minibuses heading to outlying districts such as Harmancık, Buyukorhan, and Keles.

Additionally, it is important to note that the University, Emek, and Kestel stations serve as key launch points for the Bursaray system, facilitating connections to different transportation modes. While buses and minibuses complement the Bursaray lines, they are often hampered by traffic congestion, leading to inconsistent travel times. This has been a common concern among the public transport users, highlighting the need for improved efficiency and reliability across all modes of transportation in Bursa.

The daily number of passenger data for Bursaray was obtained from the Bursa Municipality Department of Transportation for the period between January 2019 and November 2021 (see Figure 2). Before the Covid-19 pandemic, the daily number of passengers was up to 300.000; however, the demand dropped significantly during the first phase of the pandemic. The demand increased in the third quarter of year 2020; but it dropped slightly during the second phase of the pandemic. During 2021, the demand has increased slowly; however, it could not have reached the pre-pandemic conditions.

Table 1 *Descriptive statistics for sociodemographic and working status*

Parameters	Units (frequency)
Gender	Female (489); Male (498)
Age group	18-25 (538); 26-40 (374); 41-55 (62); 56-70 (13)
Education	Primary (11); High school (461); Undergraduate (416); Post-graduate (99)
Employment	Unemployed (54); Part-time employed (43); Full-time employed (385); Self-employed (33); Student (472)
Working status	Unemployed (54); Office (452); Flexible (481)

Table 2 *Descriptive statistics for travel pattern*

Parameters	Units (frequency)
Daily average commuting distance	Less than 2 km (288); 2-5 km (192); 5-10 km (166); Over 10 km (341)
Travel mode before	Micromobility (17); Private motor vehicle (348); Taxi (5); Public Transport (573); Walking (44)
Travel mode after	Micromobility (26); Private motor vehicle (564); Taxi (15); Public Transport (272); Walking (110)
Frequency of using public transport before	Less than 5 days (461); 5 days (236); 6 days (142); 7 days (148)
Frequency of using public transport after	Less than 5 days (827); 5 days (100); 6 days (41); 7 days (19)
Frequency of using private motor vehicle before	Less than 5 days (690); 5 days (93); 6 days (32); 7 days (172)
Frequency of using private motor vehicle after	Less than 5 days (563); 5 days (102); 6 days (63); 7 days (259)
Frequency of walking before	Less than 5 days (449); 5 days (191); 6 days (90); 7 days (257)
Frequency of walking after	Less than 5 days (647); 5 days (128); 6 days (55); 7 days (157)
Motivation of choosing the travel mode before	Environmental concerns (51); Costs (393); Travel time (444); Social distance (99)
Motivation for choosing the travel mode after	Environmental concerns (31); Costs (133); Travel time (132); Social distance (691)

Table 3 *Descriptive statistics for perceptions on urban light rail*

Parameters	Survey questions	Units (frequency)
Infrastructure	What is your perception on URL infrastructure? Likert Scale 1-6, where 6 corresponds to the best possible score and 1 to the worst.	1 (127); 2 (155); 3 (245); 4 (286); 5 (145); 6 (29)
Safety	What is your health-related safety perception on using URLs after the pandemic?	Definitely unsafe (469); Unsafe (384); Moderate (107); Safe (23); Definitely safe (4)
Stress/anxiety	Do you feel stressed/anxious while using URLs after the pandemic? Likert scale 1-5, where 1 corresponds to completely yes and 5 to completely no	1 (18); 2 (31); 3 (67); 4 (383); 5 (488)
Improvement on infrastructure	Do you prefer using URLs after the pandemic condition if the infrastructure improves? Likert scale 1-5, where 1 corresponds to completely no and 5 to completely yes	1 (99); 2 (158); 3 (260); 4 (380); 5 (90)

As mentioned in the literature review, passengers had significant hesitations or concerns about using the public transport during the pandemic crises. Therefore, the study in this paper has surveyed to understand passengers' perceptions.

The survey was conducted with randomly selected 987 local participants in December 2020. The participants had been using the light rail at least once a week before the pandemic. The questions were distributed via the Google survey platform. The minimum sample size for the study area was calculated using the Krejcie and Morgan formula [55] (Equation (1)). In this study, the population size was 2,056,140 [56] and the p-value was 0.5 (maximum variability). The confidence level was decided at 95% $\left(\chi^2 = 3.841\right)$ and the margin of error was ±5%. The minimum required sample size was calculated as 384, which was less than the sample size of 987 in this study. The survey questions were divided into three categories: sociodemographic variables, travel patterns and perceptions of public transport. The frequency analysis for each variable is given in Tables 1, 2 and 3.

$$n = \frac{\chi^2 Np(1-p)}{e^2(N-1) + \chi^2 p(1-p)}, \quad (1)$$

where: N is the population size,
n is the sample size,
e is the margin of error,
χ is the value of the chi-square distribution having a degree of freedom of one at a certain confidence level,
p is population proportion.

The method for analyzing the categorical variables was carried out in four steps (see Figure 3). After gaining a fundamental understanding of the dataset by descriptive statistics in step 1, before-after comparison analysis was conducted in step 2 and step 3. Wilcoxon signed rank test is a non-parametric analysis for comparing pairs of data for the ordinal variables [57]. In this study, the variables, namely frequency of using public transport, frequency of using private motor vehicle and frequency of walking were analyzed with Wilcoxon signed rank test. When the variables are in a nominal structure, McNemar-Bowker test should be conducted [58]. Therefore, before-after comparison analysis for the variables, namely the travel mode and motivation of choosing the travel mode, were analyzed with McNemar-Bowker test.

In step 4, a prediction model was developed. The investigated dependent variables were on a categorical Likert Scale from 1 to 5. Therefore, the ordered logit model was selected to be applied to develop a prediction regression [51]. The assumptions of the ordered logit model should be met: i) the dependent variable is ordinal categorical, ii) independent variables are either categorical or continuous, iii) ignorable or no multicollinearity and iv) parallel lines [59]. Meeting

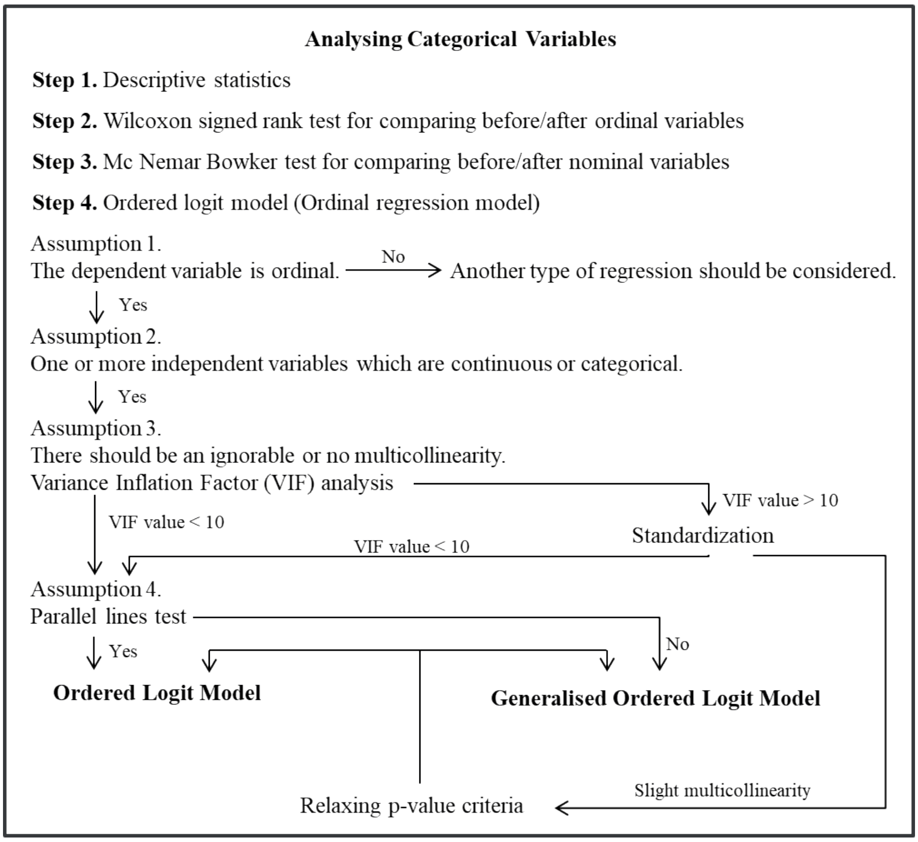

Figure 3 *Methodological framework*

these assumptions is compulsory for applying the ordered logit regression; however, they are frequently violated in studies [60]. If the assumptions are violated, generalized ordered logit model should be applied to relax the assumptions [61]. The study in this paper examined each assumption of the ordered logit model in step four and developed the prediction model based on the results. The equation generalized ordered logit model is given as follows [59]:

$$P(Y_i > j) = g(X\beta_j) = \frac{\exp(\alpha_j + X_i\beta_i)}{1 + \{\exp(\alpha_j + X_i\beta_j)\}}, \quad j = 1, 2, \ldots, M-1, \tag{2}$$

where M is a number of categories of the ordinal ranked responses of the dependent variable, and j is a number of compared categories. If M = 3, the number of compared categories is two: for j = 1 category 1 is contrasted with categories 2 and 3, and for j = 2 categories 1 and 2 are contrasted with category 3. The probability Y can be estimated as given below:

$$P(Y_i = 1) = 1 - g(X_i\beta_i), \tag{3}$$

$$P(Y_i = j) = g(X_i\beta_{j-1}) - g(X_i\beta_j), \quad j = 2, \ldots, M-1, \tag{4}$$

$$P(Y_i = M) = g(X_i\beta_{M-1}). \tag{5}$$

4 Results

Wilcoxon signed rank test showed that there has been a statistically significant decrease in public transport use and walking frequency after the pandemic, compared to before. However, a reverse outcome was observed for private motor vehicle frequency after compared to before. The participants had a model shift from public transport and walking to private car use (see Table 4). This outcome has been supported by the results of McNemar-Bowker test that there has been a statistically significant travel mode change comparing before and after the pandemic. In addition, the motivation for choosing the travel mode has been different before and after the pandemic (see Table 5). Before the pandemic, the participants tended to choose their daily travel mode regarding mostly costs and travel time. However, after the pandemic period, the participants started to prioritize social distancing.

The results from the comparative analysis suggested that the pandemic has changed the participants' daily travel behavior. The further step of the analysis was exploring the perceptions of the participants on public transport, to identify the impacts on their modal shift. A prediction analysis was carried out by applying an ordered logit model with examining the four assumptions. The analysis started with checking the first assumption which was "the dependent variable should be ordinal". The study in this paper had four prediction models for each dependent variable, namely perception on infrastructure (Model 1), safety (Model 2), stress/anxiety (Model 3), and improvement on infrastructure (Model 4). These dependent variables were collected on the Likert Scale (from 1 to 5); therefore, the dependent variables in the models were in ordinal structure and the first assumption was approved. The second assumption was "there should be one or more predictor variables and these should be continuous, ordinal or categorical". The predictor variables in this study were gender, age group, education, employment, working status and daily average commuting distance. Therefore, the second assumption was approved. The third assumption was "there should be ignorable or no multicollinearity

***Table 4** Wilcoxon signed-rank test*

Variables	Z	Negative mean ranks[c]	Positive mean ranks[d]	Asymptotic Significance (2-tailed)
Public transport use frequency before vs. after the pandemic	-17.273[a]	215.63	125.26	0.00*
Private motor vehicle use frequency before vs. after the pandemic	-8.778[b]	122.97	150.66	0.00*
Walking frequency before vs. after the pandemic	-10.054[a]	211.13	172.80	0.00*

[a]based on positive ranks; [b]based on negative ranks; [c]frequency after < frequency before; [d]frequency after > frequency before; *statically significant at 95% confidence level

***Table 5** McNemar-Bowker test*

Variables	Value	Degrees of freedom	Asymptotic Significance (2-sided)
Travel mode before vs. after the pandemic	251.394	8	0.00*
Motivation of choosing the travel mode before vs. after the pandemic	590.378	6	0.00*

*statically significant at 95% confidence level

***Table 6** Testing multicollinearity for predictor variables with Variance Inflation Factors (VIF)*

Predictor variables	VIF Values			
	Model 1	Model 2	Model 3	Model 4
Gender	1.05	1.05	1.04	1.04
Age group	1.36	1.37	1.37	1.35
Education	1.39	1.38	1.38	1.37
Daily average commuting distance	1.25	1.25	1.25	1.17
PT frequency	1.06	1.06	1.06	-
PT infrastructure	-	1.06	1.13	-
PT safety	1.27	-	1.10	-
PT stress/anxiety	1.29	1.05	-	-

PT = public transport

***Table 7** Test of parallel lines*

Model[a]	Dependent variable	Chi-Square	Degrees of freedom	Significance
Model 1	PT infrastructure	104.64	84	0.06
Model 2	PT safety	1321.09	66	0.00*
Model 3	PT stress/anxiety	126.61	66	0.00*
Model 4	Improvement on PT infrastructure	63.24	30	0.00*

[a]the null hypothesis stated that the location parameters (slope coefficients) were the same across response categories

*statistically significant at 95% confidence level

***Table 8** Model 1 - Ordered Logit Model*

Variables	Coefficient	P- Value	Odds ratio	95% confidence interval for odds ratio	
				Lower	Upper
Infrastructure[a] dependent variable					
Gender	-0.07	0.56	0.93	0.74	1.17
Age group	-0.31	0.00*	0.77	0.61	0.89
Education	-0.06	0.52	0.94	0.78	1.14
Daily average commuting distance	-0.13	0.01*	0.88	0.80	0.97
ULR using frequency	0.07	0.48	1.07	0.88	1.30
Safety	0.66	0.00*	1.93	1.64	2.27
Stress/anxiety	-0.10	0.20	0.91	0.79	1.05

*statistically significant at 95% confidence level

[a]outcome variable

between predictor variables". The VIF analysis was carried out to explore multicollinearity (see Table 6). The VIF values less than 10 for each predictor suggested that there has been no multicollinearity and the third assumption was approved.

The fourth assumption was test of parallel lines, which was given in Table 7. The results suggested that the assumption was violated for Models 2, 3 and 4. Therefore, ordered logit model was applied only for the Model 1. Generalized ordered logit model was used for the Models 2, 3 and 4 in order to relax the fourth assumption of ordinal regression. The Model 1 suggested that an increase in daily average commuting distance reduces the level of perception on infrastructure (see Table 8). The road users who travel longer distance found the ULR system infrastructure of lower quality. In addition, the level of perception on infrastructure reduced for the higher age groups. On the other hand, one unit increase in safety perception increased the perception on infrastructure by 93%.

Generalized ordered logit was applied in the Model 2, Model 3 and Model 4. In these three models, the dependent variables were road users' perceptions in Likert Scale from 1 to 5. Therefore, the number of comparison groups was four (j = 1,2,3 and 4). As shown in Model 2, higher quality of infrastructure had a consistent positive impact on feeling safer while using the ULR (p=0.00) (see Table 9).

The other consistent impact for all the comparison groups was observed for education. The participants,

Table 9 *Model 2 - Generalized Ordered Logit Model*

Variables	j = 1		j = 2		j = 3		j = 4	
	Coefficient	P- Value	Coefficient	P- Value	Coefficient	P- Value	Coefficient	P- Value
Safety perception[a]								
Gender	0.39	0.01**	-0.20	0.34	-0.95	0.04**	-0.47	0.70
Age group	0.05	0.68	0.05	0.68	0.05	0.68	0.05	0.68
Education	0.21	0.06*	0.21	0.06*	0.21	0.06*	0.21	0.06*
Daily average commuting distance	0.02	0.77	0.02	0.77	0.02	0.77	0.02	0.77
PT frequency	-0.08	0.47	-0.08	0.47	-0.08	0.74	-0.08	0.47
PT infrastructure	0.41	0.00**	0.41	0.00**	0.41	0.00**	0.41	0.00**
PT stress/anxiety	-1.07	0.00**	-0.97	0.00**	-1.53	0.00**	-1.86	0.00**

*statistically significant at 90% confidence level

**statistically significant at 95% confidence level

[a]outcome variable

Table 10 *Model 3 - Generalized Ordered Logit Model*

Variables	j =1		j =2		j =3		j =4	
	Coefficient	P- Value	Coefficient	P- Value	Coefficient	P- Value	Coefficient	P- Value
PT Stress/Anxiety[a]								
Gender	4.06	0.00**	0.13	0.69	0.19	0.39	0.59	0.00**
Age group	-2.95	0.00**	0.13	0.61	0.02	0.91	-0.24	0.05**
Education	0.16	0.15	0.16	0.15	0.16	0.15	0.16	0.15
Daily average commuting distance	1.29	0.00**	-0.01	0.96	0.09	0.33	0.10	0.11
PT frequency	-0.13	0.24	-0.13	0.24	-0.13	0.24	-0.13	0.24
PT infrastructure	-0.07	0.21	-0.07	0.21	-0.07	0.22	-0.07	0.21
PT safety	0.22	0.57	-1.36	0.00**	-1.27	0.00**	-1.44	0.00**

*statistically significant at 90% confidence level

**statistically significant at 95% confidence level

[a]outcome variable

Table 11 *Model 4 - Generalized Ordered Logit Model*

Variables	j =1		j =2		j =3		j =4	
	Coefficient	P- Value	Coefficient	P- Value	Coefficient	P- Value	Coefficient	P- Value
Improvement on PT infrastructure[a]								
Gender	0.73	0.00**	0.37	0.01**	0.02	0.89	-0.76	0.00**
Age group	-0.26	0.09*	-0.27	0.02**	-0.10	0.37	-0.57	0.01**
Education	0.05	0.65	0.05	0.65	0.05	0.65	0.05	0.65
Daily average commuting distance	0.02	0.64	0.02	0.64	0.02	0.64	0.02	0.64

*statistically significant at 90% confidence level

**statistically significant at 95% confidence level

[a]outcome variable

who had lower education level, perceived less safe while using ULR (p = 0.06). In addition, the participants tended to feel less stressed when they feel safer (p = 0.00). In addition, the same result was observed in the Model 3 (see Table 10). The participants in higher age groups tended to not prefer using URL after the pandemic condition even if the quality of infrastructure would be improved (see Table 11). The influence of each variable, namely gender in Models 2, 3 and 4, age groups and daily average commuting distance in Model 3, on the dependent variables were not found consistent between comparison groups. Therefore, a further investigation should be carried out by considering the limitations of the study in this paper.

5 Discussion

Logistic regression has been a widely used prediction technique to analyse the categorical variables. However, if the assumptions are violated, the results may be biased. Therefore, the assumptions should be checked carefully. The study in this paper applied a deeper analytical technique namely a generalized ordered logit model to analyse the categorical dependent variable. The results suggested that logistic regression should not be applied before exploring the multicollinearity and applying the test of parallel lines.

Regarding the outcomes of the statistical tests and prediction models, the literature review revealed a global decrease in public transportation use during the peak of the Covid-19 pandemic [6], which aligns with our findings indicating a statistically significant decrease in public transport use and walking frequency after the pandemic compared to before. These changes were further supported by the results demonstrating a shift in travel behavior among participants. However, the observed reverse outcome for private motor vehicle frequency after the pandemic highlights a noteworthy mode shift that warrants a detailed examination. This shift was more pronounced than suggested in some studies [10, 16], emphasizing the need to explore the nuances of travel behavior changes in different contexts. It was highlighted that the regional, sociodemographic and socioeconomic variations occurred in public transportation use during the pandemic [15]. Our results support these findings, indicating that participants exhibited a model shift away from the public transport and walking, particularly notable among certain sociodemographic groups. This aligns with the studies [24, 34], which indicated that elderly individuals were less likely to use public transport, emphasizing the role of sociodemographic factors in shaping travel behavior.

The importance of rebuilding trust in public transportation was a recurrent theme in the literature [13, 23-25, 54], and our study underscores this challenge. The observed mode shift has significant implications for urban planning and transportation policies. Policymakers need to address the newfound emphasis on social distancing in travel mode choices and consider measures that enhance the perceived safety of public transportation to encourage to use. The literature emphasized the impact of governmental measures on public transportation habits and creating different strategies [44], and our study corroborates these trends.

A shift in motivation for choosing the travel modes before and after the pandemic emerged from our results, echoing the findings from the literature [1-4]. The change from cost and travel time considerations to prioritizing social distance suggests a fundamental shift in public perceptions and priorities. This aligns with the study [27] conducted in Athens, which found that the use of public transportation decreased due to a decrease in the desire to share indoor space after the pandemic. As clearly seen in the discussion, unexpected and traumatic health conditions can deeply affect the travel behavior, preferences and perceptions. A further study focused on sustainable transportation design after Covid-19 for Melbourne and it was stated that the infrastructure of electric vehicles was insufficient and reducing carbon emission was not achievable due to the shift from public transport to private motor vehicles [62]. Associating this result with the outcomes in this paper suggests that future studies should focus on improving the sustainable transport infrastructure to reduce the safety concerns under the health issues. It is also noted here that governmental authorities should consider income support program in ensuring the continuity of public transportation services [63].

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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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