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Identification of key determinants of personal safety perception at bus stops using proportional odds logistic regression

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Abstract

Complex vehicle-pedestrian interaction near the bus stop affects the safety perception of users, but the subjective nature of perceived safety and the lack of specific measurement techniques makes its estimation further laborious. This paper identifies factors influencing safety perceptions of bus users by employing Ordered Logistic Regression analysis. The study focussed on five dimensions; bus stops' design and surrounding facilities, traffic characteristics, and travellers' individual, travel and accident characteristics. The results demonstrated that increased vehicular flow, absence of footpath, crossing facility and safety barrier would scale down the perceived safety. Furthermore, the respondent's age, education, frequency of travelling by bus, familiarity with the bus stop, and previous accident experience are significant predictors of perceived safety. Results concluded that females perceived less safe, and no effects can be attributed to the household vehicles and income. Regarding road shoulder width, 1-2 meters is the most preferred width from the travellers' safety perspective.

Keywords: Bus stop; Perceived safety; Ordered Logistic Regression; Proportional odds.

1. Introduction

Transport safety has become a pertinent issue with the increasing global population and travel demand. To combat the problems arising from globalization and increased motorization, non-motorized and public transportation have been given attention by policymakers and researchers in recent years. Increasing the service performance can increase bus ridership to a considerable extent, and among the measures of service performance, safety is most important. Although the authorities have undertook many inventions and programs to improve urban transport safety, travellers at public transport stops had received very limited attention. The quality of public transport is highly associated with the quality of stops. Nikolaeva, R. (2021) stated that public transport trips

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do not begin with boarding a vehicle, therefore, arriving safely at a stop is also important. Bus stops are identified as critical element of the public transport network because they act as an interface where users interact with transit vehicles, and it is the starting and ending points of bus passenger travel (Cheranchery et al., 2019). The interactions between users and vehicles generate numerous conflict points at or around bus stops resulting in dangerous events threatening the health and life of travellers.

The complex interactions with vehicles around bus stops affect the safety perception of users, and it is a significant retarder of travel satisfaction. Since travellers' perception of safety is more important than the actual level of safety (Abenoza et al., 2018), the location, design, and the surrounding environment should be such that they shall meet the user's expectations (Tubis et al., 2021). Perceived safety is a subjective measurement of safety, signifying the perceived degree of risks, and it has not been received the deserved importance in many of the previous research. Moreover, pedestrians behave based on their perceived safety. Sometimes pedestrias have a false sense of safety that makes them careless while making vital decisions, leading to higher risk of accidents. This means that perceived safety is important for understanding pedestrian behaviours and improving safety (Zhuang & Wu, 2012). Therefore, subjective safety is adopted to describe pedestrian safety from another angle. Measuring perceived safety is a powerful and cost-effective tool to assess the safety level from the perspective of actual beneficiaries. Developing a perceived safety model for bus stops will enable the quantification and assessment of the safety of travellers in and around the bus stop. This could be used to identify the perceived risk level of travellers' in a proactive manner before a crash happens. However, the lack of a specific measurement technique and the subjective nature of perceived safety make it more complex to analyse.

To perform a safety assessment, it is necessary to investigate the factors affecting the safety perception of travellers and how it varies with the waiting environment. Perceived safety is often measured on a five-point scale varying from very unsafe to very safe. Unlike linear regression, the increase or decrease is ‘stepwise’ rather than continuous, and it is unknown if the difference between steps is same across the scale (McNulty, 2021). Moreover, the difference between steps from very unsafe to safe may not be the same as from safe to very safe. Therefore, this paper identifies the factors influencing perceptions of the safety of bus users at bus stops by employing an Ordered Logistic Regression (OLR) analysis which suits ordered dependent variables.

The factors considered in this research are broadly classified into bus stops' design and surrounding facilities, traffic characteristics, and the travellers' individual, travel and accident characteristics. Even though much past research considered the effect of socio-demographic and trip characteristics on perceived safety, the effect of traffic and bus stop-related factors is less explored near a bus stop. The outcome of this study will aid engineers and planners in designing, improving and prioritising bus stop facilities to cater to the travellers' safety expectations. This paper is presented in several sections; the first section gives a brief history of similar pieces of literature. The sections following this describes the methodology adopted for the study, data collection and major findings derived from the analysis. Finally, a discussion of the results and noteworthy conclusions are presented.

2. Literature Review

Studies related to safety have turned into an emerging and relevant area of research nowadays. Factors affecting the safety of a bus stop can be broadly classified into two:

(1) subjective and (2) objective. Subjective factors include human factors, which are very difficult to measure and quantify, while objective factors constitute geometric, pavement, traffic, and environmental factors (Ye et al., 2016). The present study mainly focuses on the objective factors that can predict the subjective concept of perceived safety. This section presents relevant literatures related to perceived safety and the application of ordered logistic regression in the field of transport safety studies.

Abenoza et al. (2018) investigated the perceived safety at bus stops and the results converge on the fact that bus shelter characteristics, real-time information, previous experience of victimization, and natural surveillance affect the safety perception. Travelers are more concerned about the safety and personal offenses when traveling with children. They opined that trip’s purpose, characteristics, and frequency are insignificant while evaluating safety. Currie et al. (2013) concluded that the experience of personal safety incidents and gender influenced the perception of safety, while the impact of these factors on perceived safety was moderate compared to feelings of anxiety and discomfort associated with travelling with people we do not know. In addition, they also found that the perceived safety of young travellers was influenced by the feeling of comfort when traveling with people who were known to them. Travelers younger than 50 felt safer than older ones (Abenoza et al., 2018). Studies have found that the feeling of safety while using public transport or waiting at bus stops is more important for women than men (Abenoza et al. 2018; Sam et al. 2019). Similarly, males and younger road users tend to follow less safe pedestrian behaviour (Dinh et al., 2020). The impact of perceived safety and security on loyalty was smaller for male passengers than female passengers, while male passengers were more concerned about perceived service quality (Nguyen-Phuoc et al., 2021). Wang et al. (2020) led to some contradictory results that socio-demographic factors like education, income and years of driving experiences have no significant influence on passengers' safety behaviour. Abenoza et al. (2018) found marital status have no influence on safety and crime perceptions. Driver’s physical appearance, nature of drivers’ footwear, dressing, and grooming were also found to significantly affect safety perception (Sam et al., 2018). A study on pedestrian safety assessment in tram stops has concluded that the spatial organization and traffic in the area of tram stops have greater effect on pedestrian behaviour (Nikolaeva, R. 2021).

Michalaki et al. (2015) applied Ordinary Logistic Regression (OLR) to identify the factors that affect motorway accidents in England and found that traffic characteristics, roadway conditions and environmental conditions significantly contributed to the injury severity. Lawson et al. (2013) also used OLR to develop the perceived safety model for cyclists, and negative driver attitude was identified as a critical factor which affects the safety perception of cyclists. Champahom et al. (2022) used the combination of multiple correspondence analysis and OLR approaches to analyze the factors affecting the severity of motorcycle accidents on Thailand's arterial roads. Majumdar et al. (2021) employed OLR to identify the key determinants influencing travel satisfaction. It was found that gender, age, accessibility, level of congestion, availability and existing condition of sidewalks, bus stop safety, and security are significant predictors of travel satisfaction.

The primary objective of the present study is to identify the key determinants affecting the safety perception of travellers near bus stops. Perceived safety scores given by the respondents were taken as the dependent variable of the safety model. OLR technique is used for modelling rather than multiple linear regression analysis since the responses are measured as ordered categories. The current study categorized the contributing factors into five, such as (1) Bus stop related factors (2) Traffic factors (3) the travellers' Socio-Demographic, (4) Trip characteristics and (5) Previous accident experience.

A detailed description of the methodology and the factors are given in subsequent sections.

3. Study Design and Methods

This section depicts the survey method, its organization and distribution, and the methods used to analyze the data.

3.1 Survey description

The methodological approach considered three phases: (1) development of a questionnaire; (2) realization of the survey at selected bus stops; (3) statistical analysis and interpretation of findings. The questionnaire-based survey, field inventory and traffic survey were conducted to collect information on travellers' personal characteristics, bus stop design, and traffic characteristics, respectively. The questionnaire was designed to complete the interview within 4-6 minutes. The opinion survey was administered through face-to-face interviews based on a random sampling of the bus users waiting at 16 selected bus stops in Kerala, India. The study areas were characterized by rapid vehicular growth. At the same time, bus transportation is well established in this area, and a large number of travellers rely on public transport for their daily needs. Therefore, the feedback collected from these travellers will give a clear picture of the safety derived from their experience on the ground.

The questionnaire-based survey was designed to gather information on bus users' perceptions of safety levels at bus stops along with their socio-demographics, trip-related and accident experiences information. The socio-demographic characteristics included the respondent's age, gender, education, annual income, and vehicle ownership. Whether they are a regular user or not, trip frequency via buses, two way travelling distance and frequently used mode of travel are grouped under trip characteristics. Under the accident experience, information about their previous personal accident experience and accident victimization was recorded. Bus stop-related factors covered the presence of footpaths, crossing facilities and safety barriers at bus stops. The road shoulder width, the distance of the bus stop from the edge of the road shoulder, and the distance of the bus stop from the junction also come under bus stop-related factors (refer Table 2 for description of variables used in modelling). Perceived safety is assigned five levels and the respondents were asked to rate their overall safety perception for that bus stop from very unsafe (1) to very safe (5).

The field inventory survey gathered information on the presence and absence of footpaths, safety barriers and crossing facilities at the bus stop. Additionally, geometric details on the width of the road shoulder, distance of the bus stop from the edge of the road shoulder, and distance of the bus stop from the junction were collected as continuous variables and are categorised into different levels. The distance of the bus stop from the edge of the road shoulder is categorised into two levels based on the threshold of one meter. Similarly, the distance of the bus stop from the junction is split into two categories, with distances less than 75 meters as one category. Road shoulder width is categorised into three levels one with less than or equal to one-meter second category covers 1-2 meters, and the third covers remaining with a width greater than 2 meters. Figure 1 displays the data extracted based on field inventory survey. A two-hour traffic survey was conducted to determine pedestrian and vehicular flows at the selected locations. A video-graphic survey was conducted at the same time as the questionnaire survey was conducted. Later, vehicle and pedestrian count details were extracted by watching and analyzing the recorded videos.

The collected information was then analyzed using the ordered logistic regression model, with the expectation to provide detailed information on perceived safety levels. The findings could serve as a reference for formulating effective measures and policies to improve perceived safety.

W_SHLDR=2.5m (3)
D_SHLDR=0 (1)
No footpath (0)
No crosswalk(0)
Safety barrier is present (1)
(Red rectangle)
D_JUN=80 meter (0)

Figure 1: Data extraction from field inventory survey (values in brackets represent the categories)

3.2 Ordered logistic regression model

In certain studies, the dependent variable may have more than two categories, which could be ordered logically. An ordinal analysis can give different and much more robust results than an analysis that ignores the ordinality (Clogg & Agresti, 1985). The common practice in analyzing ordered categorical variables ignores the response variable's categorical nature and uses standard parametric methods. However, applying linear regression to model this variable is very complex when the ordinal variables' categories do not follow an approximate normal distribution (Rasca & Saeed, 2022). In addition, linear regression models with ordinal outcomes may have non-sensical predictions outside the observed outcome range and non-constant error variance (Fullerton & Xu, 2016). Therefore, most studies prefer to apply the methods developed specifically for ordinal dependent variables, such as the ordered logistic regression technique.

The ordered logit model is an extension of the logistic regression models in which the dependent variable of interest is categorical and has a meaningful order with more than two categories or levels (Bellizzi et al., 2018). This modelling technique is based on the cumulative probabilities of the predictor variables (Champahom et al., 2022). The ordered logit model for perceived safety can be represented as in equation 1 (Majumdar et al., 2021). Where X = a vector of variables determining perceived safety, β = a vector of parameters, and ε = a random disturbance assumed to be logistically distributed with mean = 0 and variance = 1 (Majumdar et al., 2021; Champahom et al., 2022). The error term in ordered logistic regression is assumed to follow a logistic distribution (Rasca & Saeed, 2022). The ordinal variable Y can be expressed as a function of another continuous, unmeasured latent variable Y^*, which will determine the value of the observed ordinal variable Y based on various threshold points (Bellizzi et al., 2018). The value of the observed variable Y_i depends on whether or not if a particular threshold (k_i) was crossed, and this could be found using the following formulae (2)-(4) (Bellizzi et al., 2018). The following equations corresponds to 3 number of levels.

$$Y^* = \beta X + \varepsilon \quad (1)$$
$$Y_i = 1 \quad \text{if } Y_i^* \leq k_1 \quad (2)$$
$$Y_i = 2 \quad \text{if } k_1 \leq Y_i^* \leq k_2 \quad (3)$$
$$Y_i = 3 \quad \text{if } Y_i^* \geq k_2 \quad (4)$$

where k_1, k_2 and k_3 represent the threshold values for the categories. An important underlying assumption is that no input variable disproportionately affects a specific level of the outcome variable. This assumption is commonly known as the proportional odds assumption. If the assumption is violated, the modelling approach fails, which is the major consideration in the validation process (McNulty, 2021).

4. Results

The following subsections contain the analysis of the perceived safety model developed for bus users at bus stops. This part begins with the variables' summary statistics and concludes with the ordinal regression model.

4.1 Descriptive statistics

The survey data to be analyzed were collected from 399 bus users, which included 46.6% men and 53.4% women. Since the study area has a higher percentage of male license holders (59.13%) than females (30.04%), it can be concluded that more females rely on public transport like the bus. The age groups 18-24 and 45-60 together comprised around 50% of the total respondents, and nearly 12% of the respondents are aged above 60. As per the respondents' education level, 62.1% had less than a bachelor's degree, 28.1% had only a bachelor's degree, and 9.8% reported an education level higher than a bachelor's degree. A significant proportion of the respondents (79%) have an annual income of less than 3 lakh Indian Rupees, revealing that bus transport is preferable for low and middle-income groups, and it might not look attractive for high-income groups. All the sample characteristics indicate that it accurately represents the population being studied. Table 1 presents the summary of the descriptive statistics of the collected samples. Additional details like two-way travelling distance via bus, frequently used mode of travel and purpose of travelling by bus were also collected to get additional information regarding the travel characteristics of the respondents. 52.6% of the respondents use the bus for short-distance trips, while 8.1% rely on the bus for travel distance exceeding 120 km. The summary statistics reported that approximately 71.4% of the respondents were regular users of that particular bus stop where they waited, while 28.6 were not.

Table 1: Summary of descriptive statistics

Description	*Score*	*Description*	*Score*
No. of respondents:	399	Number of bus stops:	16
Gender: (GEN)		License: (LIC)	
Female	53.4%	Yes	43.6%
Male	46.6%	No	56.4%
Age: (AGE)		Annual household income: (INC)	
< 18	6.3%	< 1 Lakh	43.4%
18 – 24	24.8%	1-3 Lakh	35.6%
25 – 34	17.0%	3-5 Lakh	15.0%
35 – 44	16.5%	5-10 Lakh	5.3%
45 – 60	23.8%	>10 Lakh	0.8%
> 60	11.5%	Two-way traveling distance:	
Education: (EDU)		< 20 km	52.6%
Up to matriculation	30.9%	20 – 40 km	23.4%
HSE	18.7%	40 – 80 km	10.2%
ITI/Diploma	12.5%	80 – 120 km	5.7%
Graduate	28.1%	> 120 km	8.1%
PG and above	9.8%	Frequently used mode of travel:	
Frequency of bus trip: (FREQ_TR)		Bus	58.1%
Frequently	60.3%	Two-Wheeler	28.1%
Once in a week	14.3%	Car	9.4%
Once in a month	10.3%	Train	1%
Once in 3 months	4.3%	Auto	3.4%
Very rarely	10.8%	Purpose of travelling in bus	
Accident Experience:		Education	26.6%
Victim of accident (ACC_VIC)	18%	Work	52.3%
Witness accident (ACC_WIT)	23.1%	Recreation/Shopping	<1%
Number of vehicles in the house (T_VEH)		Medical	4.4%
None	26.8%	Other	16.2%
1	39.6%	Perceived Safety: (PER_SAF)	
2	22.8%	Very unsafe	2.5%
>2	10.8%	Unsafe	18.5%
Regular User: (REG_US)		Neutral	54.1%
Yes	71.4%	Safe	21.3%
No	28.6%	very safe	3.5%

4.2 Ordered Logistic Regression

The modelling experiment was performed in SPSS 25.0 software. With regard to studying the factors that influence safety perceptions at bus stops, 17 variables were considered as explanatory variables in the model. Perceived safety measured on a scale of 1-5 is taken as the dependent variable. Out of the 17 selected factors, PED_FLOW and VEH_FLOW (hourly flow rate of pedestrians and vehicles) were continuous variables. Presence of footpath (FPATH), presence of crossing facility (CROS), previous accident victimization (ACC_VIC), previous accident witnessing (ACC_WIT), being a regular user (REG_US), gender (GEN), and presence of safety barrier (SA_BAR) are introduced as dichotomous variables. Width of the road shoulder (W_SHLD), the distance of the bus stop from the edge of the road shoulder (D_SHLDR), distance to the nearest junction (D_JUN), age of the respondent (AGE), frequency of travelling by bus (FREQ_TR), total household vehicles (T_VEH), income (INC), and educational qualification (EDU) are provided as ordinal variables.

Regarding the trip-related factors, the total distance travelled in the bus, the purpose of travelling in the bus and the frequently used mode are not taken for modelling due to the high correlation between the variables (all correlation values were more than 0.8). Table 2 gives a detailed description of the variables used for modelling and how they coded in the SPSS software.

Table 2: Detailed description of variables used for modelling

Variable	*Categories*	*Label*	*Variable*	*Categories*	*Label*
Socio-Demographic					
Gender: (GEN)	Female	0	Annual household income:	< 1 Lakh	1
	male	1	(INC)	1-3 Lakh	2
Age: (AGE)	< 18	1		3-5 Lakh	3
	18 – 24	2		5-10 Lakh	4
	25 – 34	3		>10 Lakh	5
	35 – 44	4	Education: (EDU)	Up to Matriculation	1
	45 – 60	5			
	> 60	6		HSE	2
Number of vehicles in	None	0		ITI/Diploma	3
the house (T_VEH)	1	1		Graduate	4
	2	2		PG and above	5
	>2	3			
Accident experience					
Victim of accident	Yes	1	Witness accident	Yes	1
(ACC_VIC)	No	0	(ACC_WIT)	No	0
Trip characteristics					
Frequency of bus trip:	Frequently	1	Regular User: (REG_US)	Yes	1
(FREQ_TR)	Once in a week	2		No	0
	Once in a month	3			
	Once in 3 months	4			
	Very rarely	5			
Bus stop related factors					
Presence of footpath	Yes	1	Safety barrier (SA_BAR)	Yes	1
(FPATH)	No	0		No	0
Presence of crossing	Yes	1	Distance of bus stop from	≤1m	1
facility (CROS)	No	0	edge of road shoulder (D_SHLDR)	>1m	0
Width of the road	≤1m	1	Distance of bus stop from	≤75m	1
shoulder (W_SHLD)	1-2	2	junction (D_JUN)	>75m	0
	>2	3			
Traffic factors					
PED_FLOW	Continuous		VEH_FLOW	Continuous	

Multi-collinearity was checked using the variance inflation factor (VIF), and the results are presented in Table 3. VIF values for all independent variables are below 5, which confirms that no multi-collinearity problem exists between the selected variables. Therefore, all seventeen selected variables were included for further analysis. Tolerance is the inverse of the VIF value, defined as the proportion of variance of the variable in question not explained by regression on the remaining explanatory variables. VIFs above ten or tolerances below 0.1 are a cause of concern (Fricker, 2001).

Table 3: Multi-collinearity test result

Variable	*Tolerance*	*VIF*
D_SHLDR	0.435	2.296
PED_FLOW	0.507	1.973
VEH_FLOW	0.277	3.612
FREQ_TR	0.759	1.318
REG_US	0.825	1.213
ACC_VIC	0.701	1.426
ACC_WIT	0.697	1.435
GEN	0.852	1.173
AGE	0.806	1.241
EDU	0.630	1.588
INC	0.617	1.620
T_VEH	0.621	1.610
W_SHLD	0.216	4.634
SA_BAR	0.197	4.079
CROS	0.304	3.289
FPATH	0.493	2.027
D_JUN	0.457	2.187

The details of ordinary logistic regression and model fit indices are given in Table 4. The results from the likelihood ratio test showed that there is a significant improvement in the fit of the final model (χ^2 = 262.269, $p < 0.05$) containing the complete set of predictors compared to the intercept-only model. Both Pearson (χ^2 = 1019.158, $p > 0.05$) and deviance goodness-of-fit indices (χ^2 = 668.742, $p > 0.05$) suggests that we can accept the null hypothesis; i.e., the observed data is having goodness of fit with the fitted model. The pseudo R^2 value is used in OLR, which can vary between 0 and 1. R^2 is based on the model's log-likelihood compared to the baseline model's log-likelihood (Champahom et al., 2022). In this study, the pseudo R^2 of the model is 0.482 or 48.2% (Cox and Snell). In other words, the set of variables can explain 48.2% of the variation in safety.

Table 4: Model fit indices of the ordinal logistics regression analysis

Model	*-2 Log Likelihood*	*Chi-Square*	*df*	*Sig.*
Model Fitting Information				

Model	*-2 Log Likelihood*	*Chi-Square*	*df*	*Sig.*
Intercept Only	937.942			
Final	675.673	262.269	33	.000
Goodness of Fit				
Pearson	-	1019.158	1187	0.816
Deviance	-	668.742	1187	1.000
R^2: Cox and Snell = 0.482; Nagelkerke = 0.532				

Table 5 illustrates the results of OLR for perceived safety among bus users. In order to explain the categories that influence perceived safety, each category's parameter estimates and odd ratios were compared with the reference categories in their group. Estimates greater than zero indicated that an increase in independent variables was related to an increase in perceived safety.

Table 5: Ordered logistic regression parameter estimates and odds ratios

Variable	*Categories*	*Reference Category*	*Estimate*	*Std. Error*	*Sig.*	*Odds ratio*
VEH_FLOW			-0.016	0.005	.001***	0.984
PED_FLOW			0.094	0.029	.001***	1.099
REG_US	0	1	-0.771	0.269	.004***	0.463
ACC_VIC	0	1	1.840	0.358	.000***	6.299
ACC_WIT	0	1	1.277	0.324	.000***	3.586
GEN	0	1	-0.830	0.245	.001***	0.436
AGE	1	6	2.211	0.563	.000***	9.125
	2		1.824	0.465	.000***	6.197
	3		2.157	0.504	.000***	8.644
	4		2.142	0.475	.000***	8.521
	5		0.807	0.406	.047**	2.240
EDU	1	5	1.925	1.125	.087*	6.858
	2		1.123	0.518	.030**	3.073
	3		1.691	0.473	.000***	5.426
	4		0.561	0.446	.208	1.753
INC	1	5	-2.943	1.468	.155	0.052
	2		-2.481	1.450	.187	0.084
	3		-2.306	1.451	.112	0.100
	4		-2.599	1.465	.276	0.074
T_VEH	0	3	-0.592	0.479	.217	0.553
	1		-0.642	0.445	.150	0.526
	2		-1.024	0.438	.194	0.359

Variable	*Categories*	*Reference Category*	*Estimate*	*Std. Error*	*Sig.*	*Odds ratio*
W_SHLD	1	3	-1.680	0.855	.049**	0.186
	2		1.878	0.899	.037**	6.539
SA_BAR	0	1	-2.041	0.978	.037**	0.130
CROS	0	1	-1.762	0.610	.004***	0.172
FPATH	0	1	-2.233	0.842	.008***	0.107
D_JUN	0	1	-0.873	0.634	.019**	0.418
FREQ_TR	1	5	0.881	0.409	.031**	2.414
	2		-1.061	0.482	.028**	0.346
	3		-0.261	0.502	.604	0.771
	4		-0.864	0.651	.185	0.421
D_SHLDR	0	1	-1.321	0.399	.001***	0.267

*** $p < 0.01$ (significant at 99% confidence interval)
** $p < 0.05$ (significant at 95% confidence interval)
* $p < 0.10$ (significant at 90% confidence interval)

4.3 Checking proportional odds assumption

The proportional odds assumption means that each input variable has a similar effect on different levels of the ordinal outcome variable (McNulty, 2021; Ari & Yildiz, 2014). The model becomes valid only if it satisfies the proportional odds outcome. This study used the Brant-Wald test to validate the assumption. A low p-value in a Brant-Wald test indicates that the coefficient does not satisfy the proportional odds assumption (McNulty, 2021). The p-value obtained exceeds 0.05 ($p= 0.997$ and $\chi^2 = 64.067$). Thus, the results could be interpreted as passing the proportional odds assumption test.

5. Discussions

The study evaluates the factors influencing the safety perceptions of bus users by employing ordered logistic regression analysis. The relationships of the dependent variables with respect to perceived safety are depicted in Figure 2 based on the estimates. The OLR results show that the household income and total vehicles owned by the family did not show any significant effect on safety perception of travellers at any level of significance. Therefore, the results for the household income (INC) and total vehicles owned (T_VEH) are inconclusive. Even though T_VEH has no significant effect on perceived safety, it has a pronounced effect on travel satisfaction (Majumdar et al., 2021).

Both the traffic factors were significant at a 99.9% confidence interval, with VEH_FLOW having negative and PED_FLOW having positive estimates. Since both flows are provided as continuous variables, lower values were taken as the base category. VEH_FLOW estimates are negative, indicating that perceived safety decreases as the flow increases. This trend is because as the vehicle flow increases, the bus user-vehicle interaction also increases, which may result in an uncomfortable and unsafe feeling in the mind of pedestrians. On the other hand, the factor PED_FLOW exhibited a different behaviour with positive estimates meaning that safety increases with increase in pedestrian flow. Leden (2002) also found that the risk of pedestrians decreased with increasing flows because of increased driver alertness and vehicles approach bigger groups at a lower speed, improving safety.

The effect of gender on perceived safety is significant, with a negative estimate (-0.830) indicating that the category under consideration feels less safe than the reference category. More clearly, since the odds ratio for GEN is less than one, it indicates that female travellers feel less safe than male travellers. The probability that a female traveller feels safe at the bus stop is only 28.82%, and the probability that they are not feeling safe is 71.17%. This result was consistent with that of a previous study by Zhuang & Wu, (2012). Fan et al. (2016) also found that Women waiting for more than 10 min in transit stops are perceived insecure than men.

For the AGE variable, all categories have a positive and significant impact on perceived safety, which decreases from the first to the second category and again decreases from the third to the fifth category. The positive coefficients indicated that the safety perceptions of young and middle age groups were significantly higher compared to older people (age >60). The unsafe feeling for the older people may be resulting from the limitation in their reaction time and mobility, which makes them feel more vulnerable to accidents. Pinto et al. (2020) also stated that mobility is one of the most common difficulties associated with age, and therefore, an age-friendly built environment is essential for elderly people. They summarized that the use of tactile paving surfaces is the best option to improve comfort and safety. Additionally, an age-friendly paving surface in the waiting area of the bus stop will increase social inclusion and incorporate the functional diversity of different age groups. Bus users in the age group <18 perceive approximately nine times safer relative to the older category aged above 60. The probability that the age group 18-24 feel safe is 86.10%. But, the coefficients of the 25-34 and 35-44 age groups were similar, which showed that the overall safety perception was almost equal for both groups. (Pajković & Grdinić-Rakonjac, 2021) showed that the perception of the overall safety situation differs related to different age group

When the education variable is considered, only three categories (up to matriculation, HSE and ITI/diploma) have a statistically significant positive impact on perceived safety. The coefficients are positive, which conveys that people with low educational qualifications feel safer at a public transit stop at a 90% confidence interval compared to the base category (PG and above). The probability that people with matriculation qualifications feel unsafe is 87.27%. This trend may be because of the increased safety awareness of educated people. Therefore, indirectly it can be concluded that increasing the safety awareness of all travellers, including drivers, could bring a secure and safe environment at bus stops.

In addition, this study also explored the predicting power of bus stop facility-related factors on perceived safety. All the six factors considered were found to be significant at a 90% level of significance. W_SHLD estimate exhibited positive and negative values for different category levels. Category 1 has negative estimate, which represents that people feel less safe at bus stops with road shoulder width less than 1 meter with a probability of only 15.68% compared to the base category (width >2 meters). Category 2 gave a rather contrasting result for road shoulder width between 1-2 meters. The results illustrated that a bus user feels unsafe at a bus stop with no dedicated footpath with a probability of 81.83%, while the probability that a user feels safe is only 18.17%. Previous research suggests that paved road shoulder has safety benefits for all road users up to 1.5 meters road shoulder width. However, the safety of users is reduced on segments having a paved road shoulder width of more than 2 meters (Singh Bisht & Tiwari, 2022). In conclusion, people feel less safe at bus stops with road shoulder width less than 1 meter and are found to be safer at 1-2 meter width. The users feel unsafe for bus stops having wider road shoulders because increased road shoulder width could provide additional width for drivers to use, which may to over-speeding and illegal overtaking.

The OLR results also show that two out of the four categories of the variable “frequency of travel” (once in a month and once in 3 months) significantly impacted the perceived safety. People who use the bus for daily commuting feel safer than the reference category (very rarely), and the probability of feeling safe at the bus stop is 70.71%. Similar findings were also observed for the variable REG_US. The travellers who are relatively new to a particular bus stop feel unsafe, with a probability of 68.35%. This result may indicate that familiarity with the bus stop due to regular use may decrease a bus user's probability of describing bus stops as less safe. Lawson et al. (2013) also found that increasing the familiarity reduces the perceived risk. Situation awareness or actual perception of elements in the environment will make the regular users more comfortable. Increasing the degree of awareness from basic perception level to highest prediction level may help them to process the information at higher levels and predict future status (Stanton et al., 2001).

Under accident experience, information about their previous personal accident experience, including accident victimization (ACC_VIC) and witnessing (ACC_WIT), were recorded. In line with a previous research (Abenoza et al., 2018), this study also concluded that users who have been a victim or had witnessed some accident in the past feel less safe at and around bus stops when compared with others who have not. The main reason is that persons with unsafe experiences will be more conscious of their surroundings and resort to safety precautions. The odds that a person with no previous accident victimization feels safe is 5.1 times higher than the odds for a person with accident victimization. In other words, the probability that a person having a previous accident feels safe at the bus stop is only 16.35%.

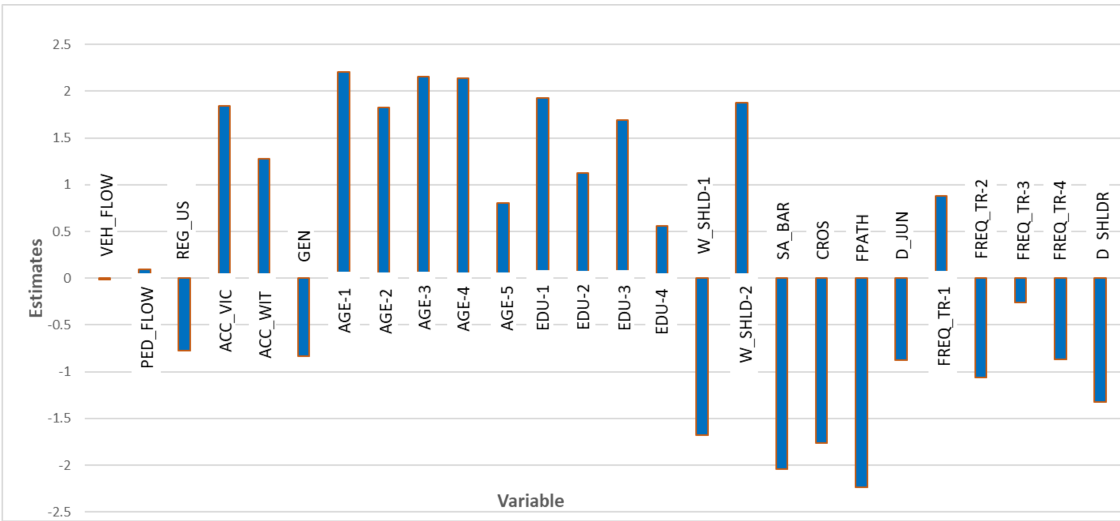

Figure 2: Relative effect of variables on perceived safety

D_JUN has a significant negative effect on perceived safety, meaning that as the distance to the junction from the bus stop decreases below 75 meters, people feel less safe than the reference category. The probability of feeling safe at this bus stop is only 29.48%. Similar findings were made by other researchers (Phillips et al., 2021; Chin and Quddus, 2003) that collisions are more likely at any bus stop near or within 75 m of a junction. Such collision probability may be responsible for the reduced safety perception. The variable CROS is found to be significant with a negative coefficient (-1.762), indicating that bus users are afraid to cross the road at the bus stop with no crossing facility. Travellers feel safe while crossing using dedicated crossing facilities, and the probability that people feel unsafe without crossing facility is 85.32%. Therefore, providing adequate crossing facilities near bus stop by considering the flow of pedestrians will positively contribute to the perceived safety.

6. Conclusions

To promote bus as a major mode of transportation, it is essential to improve the perceived safety of the mode to a level that is comparable to other modes of travel. An effort to find the safety issues associated with public transport facilities, especially bus transport, has immense potential to attract more travellers. A safe, secure, reliable, and easily accessible public transport that meets users' expectations could increase captive bus users. Nevertheless, enhancing safety inside the vehicle is just one aspect, but their safety at transit stations while waiting for service is paramount towards increasing bus ridership. This study considered ordered logit/proportional odds models rather than multinomial ones (which ignore categories' ordering), and the perceived safety is measured as ordinal. This study conducted a detailed investigation to ascertain the main factors affecting the perceived safety of bus users at bus stops. The developed model was interpreted for better policy suggestions and the following conclusions were made.

The main conclusion is that the safety associated with a bus stop may vary with socio-demographics, trip characteristics, accident history, traffic factors, and bus stop’s location and design characteristics. Socio-demographic characteristics such as age, gender and education are important factors affecting bus users' perceived safety at bus stops. Aged users and women feel less safe at bus stops than young adults and males. Since public transport has a higher ridership among women, they are frequently subjected to accidents and fear of being a victim of an accident (Chowdhury and van Wee, 2020). Hence, the authorities should focus on the users' socio-demographic profile while designing and improving the existing transit stops. Including night lighting facilities, real-time information systems, and emergency support will help build a safe waiting environment for older users and women.

Contrary to the previous research (Abenoza et al., 2018), the present study concluded that the frequency of bus trips and the familiarity of the bus stop could positively contribute to the perceived safety at bus stops. Improving service performance measures, especially safety and security, help to create a better outlook about bus transport, and will attract travellers towards public transport for their regular use. This study revealed that people with past accident records or bearing witness to an accident would have unsafe feelings in their minds. Enhancing safety measures at transit stops and spreading awareness about the safety benefits of using public transportation could improve their perception level. Behavioural-change strategies such as social comparison technique is also recommended to improve the safety perception.

In line with previous research (Phillips et al., 2021), the present study also concluded that locating bus stops within 75 meters near junctions has safety implications, negatively affecting the users' perceived safety. Similarly, the other built environment factors, bus stop-related factors and pedestrian facilities are the significant predictors of perceived safety. The effect of road shoulder width on perceived safety was contradictory to the expectation that increasing road shoulder width will improve the perceived safety level. The comfortable range for road shoulder width is 1-2 meters, and increasing it beyond 2 meters will adversely affect the perceived safety.

Regarding traffic factors, pedestrian flow and vehicular flow exhibited different effects. If increased traffic flow threatens their safety, the increase in pedestrian flow will contribute positively to their safety. Adopting suitable management measures to control the traffic flow near bus stops could be considered while planning a bus stop to improve its perceived safety. Additionally, while developing policies to attract people towards bus transport, planners could incorporate the results in their decision making to significantly improve the perceived safety of travellers. The findings also suggest that incorporating pedestrian views into the design of facilities could significantly improve the use of these facilities and, consequently, the safety and overall satisfaction.

Most of the respondents were from low and middle-income families; therefore, the scope of the present study is limited to people using bus transport. Since the study participants were purposively selected from bus stops, the perspective of other travellers' who consistently rely on their private vehicles were missed. Like most surveys, the respondents are likely to either under or over-report their safety. The research could not incorporate other influencing variables like waiting time, flooded roadway, basic amenities at bus stop, and the presence of traffic control measures on perceived safety, which may lead to a lengthy questionnaire that may reduce the response rate. Despite these limitations, the findings of the present study could provide valuable inputs towards adopting suitable measures to improve the acceptability and attractiveness of buses from the stand-point of safety. Future research should be conducted with an increased sample size covering all economic classes that could provide additional information on the influence of perceived safety on all of their mode choice decisions.

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Appendix

1. **Gender:**
   Male ☐ Female ☐
2. **Age**
   < 18 ☐
   18 – 24 ☐
   25 – 34 ☐
   35 – 44 ☐
   45 – 60 ☐
   > 60 ☐
3. **Total number of vehicles in the house**
   None ☐
   1 ☐
   2 ☐
   >2 ☐
4. **Have you ever witnessed an accident?**
   Yes ☐ No ☐
5. **Have you ever met with an accident?**
   Yes No ☐
6. **Frequency of bus trip**
   Frequently ☐
   Once in a week ☐
   Once in a month ☐
   Once in 3 months ☐
   Very rarely ☐
7. **Do you have driving license**
   Yes ☐ No ☐
8. **How much kilometres you travel in bus daily (Both directions)**
   < 20 km ☐
   20 – 40 km ☐
   40 – 80 km ☐
   80 – 120 km ☐
   > 120 km ☐
9. **Frequently used mode of travel:**
   Bus ☐
   Two-Wheeler ☐
   Car ☐
   Train ☐
   Auto ☐
10. **Purpose of travelling in bus**
   Education ☐
   Work ☐
   Recreation/Shopping ☐
   Medical ☐
   Other ☐
11. **Annual household income**
   < 1 Lakh ☐
   1-3 Lakh ☐

3-5 Lakh ☐
5-10 Lakh ☐
>10 Lakh ☐

12. **Educational qualification**

Up to Matriculation ☐
HSE ☐
ITI/Diploma ☐
Graduate ☐
PG and above ☐

13. Are you a regular user of this bus stop?

Yes ☐ No ☐

14. Please rate your feeling of safety from this bus stop

Very unsafe ☐
Unsafe ☐
Neutral ☐
Safe ☐
Very safe ☐