Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Long-term impacts of COVID-19 pandemic on travel behaviour

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A B S T R A C T

The need to understand the influence of the COVID-19 pandemic on the long-term travel behaviour of people has never been higher as a consequence of the second wave of pandemic. In this context, the current study aims to understand the willingness of people to use sustainable modes of transportation including shared modes of transport, and non-motorized transport, against non– shared modes of transport such as personal 2-wheelers and 4-wheelers in a post-vaccinated scenario. The study further models the willingness to choose public transportation under various COVID-19 preventive measures representing the perception of safety among people. An Integrated Choice and Latent Variable (ICLV) framework a employed in the modelling. The fear of contracting COVID-19 and the belief in remedial measures significantly influenced the mode choice of individuals. This highlighted a significant long-term impact of the pandemic on the travel behaviour of individuals. The study concludes by presenting different strategies that could be adopted to make the existing sustainable modes safer, and hence, more attractive.

1. Introduction

COVID-19 has had a significant long-term impact on India's urban and rural passenger mobility. After the first wave of virus infections in India, people started assuming the end of the pandemic by discarding the use of masks and by not maintaining the prescribed social distance. This led to the second wave of COVID-19 spread, which had a higher fatality rate. Particularly in India, the sharp rise in the positivity rate has claimed higher than 200,000 lives officially, the unofficial count being higher (Chakraborty et al., 2021), with an estimated 25 million people infected with COVID-19. The load on medical facilities was enormous, and the disruptions in the supply chain resulted in an all-out medical emergency. This was further worsened by the spread of secondary diseases such as black fungus.

The fear of getting infected through socialization guided the people who owned vehicles to discard the use of public transport. On the other hand, the people who did not own a private vehicle had no choice but to use the existing public transport modes irrespective of their fear. The former case reduced the use of sustainable transport like public transport modes, and the latter case increased the chance of infection if proper precautions were not taken inside the public transport. Over a longer period, two strategies that could be expected to boost the usage of public transport would be to mitigate the fear among people towards the spread of infection and to control the actual spread of infection. Both of these objectives can be achieved by vaccinating the people. As a collective stride against the virus spread, vaccination has paved the way to regain the pre-COVID-19 life standards to an extent. Vaccination was expected to give people the confidence boost they required to carry out their daily activities and travel with a sense of safety. However, despite vaccination being a preventive safeguard, people are divided on its efficacy. As vaccination was mandated for travel, protests were observed across different places of the world against this mandate. Similar protests were also observed regarding the COVID-19 protocols such as social distancing and usage of masks.

The mixed response and societal behaviour can be expected to induce a serious bias in the assumed influence of these preventive steps on the travel choices, specifically on the public transport choice. A systematic evaluation regarding the same can be done by understanding the specific perception of safety about travel in public transportation services such as bus and metro, along with the usage of non-motorized transport. In this context, the current study aims to present an understanding of the public transport and non-motorized transport (NMT) choice in a post vaccinated scenario, by addressing the following objectives:

1. To understand the impact of various psychological constructs upon the willingness to choose private non-shared vehicles over shared modes of transport such as bus, metro and pooled cabs.
2. To understand the impact of different attributes of pandemic such as vaccination, sanitization, social distancing upon the perception of the safety of people with regards to the public transportation system, using a stated preference experiment.

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3. To explore the impacts of pandemic towards willingness of people to choose non-motorized transportation such as walking and bicycling for short trips.

These objectives explore the specific impacts of the pandemic upon the behavioural intention of people towards mobility and travel. Further, the study aims to address the long-term implications of the pandemic upon the mode choice of individuals, by understanding their intended willingness to choose sustainable modes of transportation in a post-vaccinated scenario for different trip types.

The present study is organized into different sections as follows. Section 2 presents a brief literature review of the existing studies in a COVID-19 context. Section 3 discusses the data collection process and different variables collected for the analysis. Section 4 explains the methodology of the study. Section 5 presents the models estimated, the results and discussions of the analysis. Section 6 elicits the policy implications of the results, and further, concludes the study.

2. Literature review

Since COVID-19 emerged as a pandemic, people's economy, travel, and well-being took a drastic hit. In the initial days of the pandemic, travel was greatly curtailed due to the lockdown norms, and the fear of people to travel (Aaditya and Rahul, 2021a). The disruptions caused by the pandemic led to long-term implications in the behavioural intentions of individuals towards travel thus impacting the long-term mobility plans and policies. Specifically, public transportation in developing countries was observed to pose a high risk to safety and security because of over-crowding (Joewono and Kubota, 2006) . Space and service issues were observed to impact the behavioural intentions of the public to use public transportation (Park et al., 2022).

Studies show that the satisfaction from travel, be it a commute trip or a leisure trip, contributes greatly to the emotional well-being of people (De Vos et al., 2013; Gärling, 2019; Gärling and Connolly, 2021; Rahul and Manoj, 2020) and to the economic well-being of a nation (De Vos, 2020). After the first lockdown, fear of contracting the virus, induced due to the casualties of the virus and the strict lockdowns implemented by the governments, pushed the people towards a sense of uncertainty and risk aversion (Aaditya and Rahul, 2021b), thus leading to increased psychological burden and anxiety (Wake et al., 2020; Millroth and Frey, 2021). Further, the risk aversive nature pushed people towards the usage of personal vehicles and non-shared ride-hailing services (Aaditya and Rahul, 2021a). The intention of avoiding risk by travelling in a shared public transportation service led to increased sales of personal vehicles especially-four-wheelers after the lockdown.

Information plays a very important role in influencing the decisions taken by an individual (Mallinson and Hatemi, 2018). Specifically, at times of crisis, false information can increase the sense of vulnerability of a person and can manipulate the decisions taken (Torpan et al., 2021). As the process of vaccination started all over the country, vaccine hesitancy was found among many communities, where a lack of awareness about the disease prevailed. Concerns regarding the vaccination and its efficacy against the virus, lead to a lack of surety or even to an outright refusal to take vaccination (Chandani et al., 2021). The negative impact of inadequate awareness regarding the disease is reported in many other studies also (Aaditya and Rahul, 2021a; Jaber, 2021; Teo, et al., 2021). Awareness regarding the disease and its spread, and the subsequent preventive measures increases the belief of people in the COVID-19 protocols and aids in the vaccination process (Samanta et al., 2022).

In psychology, the Theory of Planned Behaviour (TPB) suggests that the behaviour of an individual is shaped by the attitude of the individual, the subjective norms and the perceived behavioural control (Ajzen, 1991). The attitude of the individual towards a particular behaviour or a decision is observed to be highly influenced by the person's belief about the decision or the behaviour. A high willingness towards using masks or social distancing can be expected from an individual if he/she believes in the effectiveness of the COVID-19 protocol. Further, the specific evaluation of a behaviour is impacted by the judgement of close friends, family and relatives, and this influences the ability to assess the situation (Shadmehr and Bueno De Mesquita, 2020). The perceived behavioural control explains an individuals perceived ease or difficulty to perform a certain behavior (Heinen, Maat and Van Wee, 2011). This aids in explaining the severe psychological effects on people because of travel restrictions (Rehman et al., 2020; Serafini et al., 2020; Ettema et al., 2016; Mondal et al., 2020; Won et al., 2020). Hence, this theoretical underpinning of TPB could be adopted to understand how lockdowns and quarantines shaped the behavioural intentions leading to long-term effects on the sustainability of transportation systems.

The Theory of Planned Behaviour (TPB) has been incorporated in discrete choice models to understand the individual psychology while making a choice. In travel behaviour studies, discrete choice models provide a mathematical framework to understand the decision process of an individual to choose from a set of mutually exclusive and collectively exhaustive set of alternatives (Ben-Aakiva and Lerman, 1985). This decision process may be influenced by different variables that are observable or latent in nature (Bouscasse, 2018). Latent psychological constructs provide a new and better understanding of the reasons behind choosing an alternative, and aid in discerning the black box of decision making (Ben-Akiva et al., 2002). Integrated choice and latent variable (ICLV) models provide an elaborate econometric framework to include latent variables in the discrete choice models (Vij and Walker, 2016). ICLV models have been successful to incorporate and explain the impact of psychological constructs, and have been used in diverse applications to explain social interactions (Kamargianni et al., 2014), attitudes (Kamargianni and Polydoropoulou, 2013; Alizadeh et al., 2019), environmentalism (Sottile et al., 2015), and influence of climate (Motoaki and Daziano, 2015).

3. Data collection and description

A mixed mode of data collection was adopted to acquire the data in the tough times of pandemic. This included online data collection using google forms as well as offline data collection. Initially the questionnaire was spread through close contacts, social media platforms such as Facebook, LinkedIn, WhatsApp, etc for a span of 2 months (2nd September 2021 to 31st October 2021). The respondents were asked to fill the forms voluntarily and were requested personally to share the same to their contacts. A total sample of 225 respondents was obtained in the online mode, till it reached to the maximum contacts possible. Following this, an offline data collection was implemented in the state of Odisha, India, where the data acquisition was performed in banks, malls, and public transit stations, by random sampling, for a period of one month (1st October to 31st October). The restrictions of COVID −19 were considerably relaxed at the time of the data acquisition, with malls, shopping centres and public transit stations partially opened, allowing the data acquisition. At the time of this data collection, 1.06 billion of residents were vaccinated with the 1st dose, with the lowest recorded positivity rate in 248 days. Most of the respondents were observed to be wearing masks but continuing their regular lifestyle of going to work places or educational institutions. A total of 245 data points were obtained from the offline data collection, the proportions of the demographics being very close to the online sample. Initial sorting and cleaning of the data points resulted in a total of 467 individual responses with a total of 62 questions. The state of residence, gender, regionality, age, maximum level of education, occupation, monthly family income, and vehicle ownership were used to understand the demographic and socio-economic spread of the sample, whose proportions are presented in Table 1.

As can be observed from Table 1, in the data, the proportions of male and female respondents were respectively 55.03 % and 44.97 %. Regionality is understood to reflect the differences in urban and rural responses about the pandemic. In the sample, 70.66 % of the data points

Table 1
Demographics.

Variable	Categories	Proportion (in percentage)	Census proportions
Gender	Female	44.97	48.49
	Male	55.03	51.51
Regionality	Urban/Semi-urban	29.55	31.2
	Rural	70.66	68.8
Age	Below 18	1.28	9.9
	18–24	56.32	9.8
	25–40	28.91	22.7
	41–56	9.21	15.18
	57–65	3.85	6.3
	Above 65	0.43	5.4
Education	Graduate & below	56.53	–
	Post Graduate & above	43.47	
Occupation	Govt and pvt employees	23.55	–
	Students	56.75	
	Business, contract and free lancers	20.13	
Income	Less than 5000	6.64	–
	5000–10000	14.13	
	10000–25000	18.20	
	25000–50000	23.13	
	50000–75000	13.49	
	75000–100000	11.35	
	Above 100,000	13.06	
Vehicle Ownership	Bi-cycle	71.09	–
	Two-wheeler	80.72	
	Four-Wheeler	36.40	
History of COVID-19 infection	Self (cov_self)	14.3	–
	Family (cov_fam)	30.6	

were understood to be acquired from rural areas. The rest were obtained from urban/semi-urban areas. The current sample consisted of a majority of respondents in the age group 18–24 (56.32 %), followed by 25–40 (28.91 %). Further, understanding the education level could be expected to give a better overview of the difference in decision making and risk-taking attitudes across the academic spectrum. In the current sample, a majority of respondents were observed having a minimum educational qualification of graduation or below (56.53 %), whereas the percentage of post-graduate and above were also significantly high (43.47 %).

Income is an important explanatory variable in understanding the mode choice of individuals. Income appears to be fairly distributed in the current sample with people earning 25,000 to 50,000 per month having the highest share (23.13 %), followed closely by people earning 10,000 to 25,000 per month (18.20 %). 80 % of the sample owned a two-wheeler, as is predominantly the case in a developing country like India, and 36.4 % of all the respondents owned a four-wheeler. Apart from these, the mode choice of individuals in the pre-COVID-19 scenario was also asked in the questionnaire to capture the captive nature of respondents to their modes. Further, the history of COVID-19 infection for the respondents and their family members was acquired to understand their experience with the virus infection. 14.3 % of respondents had a history of getting self-infected with COVID-19, and 30.6 % of respondents had a history of their family members getting infected with COVID-19.

The indicators for the latent variables used in the study along with their mean values are presented in Table 2. These indicators are measured on a likert scale of 5 levels, from least willing (1) to most willing (5), for the statements presented, from which the averages were calculated. Two categories of indicators were used to understand the perception of people: category-1 deals with the perception of individuals towards the pandemic, the COVID-19 protocols and their fear towards contracting the virus, and category-2 aims to understand the general perception of people towards personal vehicles and non-motorised transport.

Table 2
Indicators used in modelling.

I#	Indicator	Mean
Pandemic specific (Category-1)		
Ind-1	I believe wearing masks can prevent COVID-19	3.99
Ind-2	I believe there is a possibility of COVID-19 infection through socialization	1.01
Ind-3	I believe sanitization is effective in preventing COVID-19	3.56
Ind-4	My friends prefer private modes over public transportation	2.24
Ind-5	I believe if more people followed society's rules, the world would be a better place	4.22
Ind-6	I believe vaccination can prevent us from being affected by COVID19.	3.97
Ind-7	I am constantly following news updates regarding COVID-19	3.80
Ind-8	I am worried that I might get infected if I travel	3.48
Ind-9	I will panic if I/my friends/family travel during the pandemic	3.52
Ind-10	How much are you satisfied with your job performance while working from home?	3.04
Mode specific indicators (Category-2)		
Ind-11	I believe owning and using private modes is a sign of prosperity compared to non-motorised transport and public transport	2.92
Ind-12	I believe using non-motorised transport and public transport reduces environmental pollution compared to car and two-wheeler	4.07
Ind-13	The pedestrian and bicycling facilities around my place of residence are safe	3.45

4. Methodology:

4.1. Factor analysis

Factor analysis was conducted on the indicators presented in Table 2 to extract the latent factors and hence, the structure behind the indicators. The factor analysis adopted a Varimax rotation to cluster the variables. This understanding of the causal latent structure behind the indicators aided in the specification of the measurement model for the ICLV model. The indicators were loaded onto two different factors as presented in Table 3.

In Table 3, factor 1 explained the variance of indicators I1, I2, I3. It elicited the fear of individuals towards contracting the virus and is henceforth named 'fear' in further analysis, and the corresponding indicators are named fear_1, fear_2 and fear_3 respectively. Similarly, factor 2 that absorbed the impact of indicators I4, I5, I6 and I7 highlighted the belief of individuals towards measures to prevent COVID-19 infection. Factor 2 is henceforth named 'belief' in the further study, and the corresponding indicators are called belief_1, belief_2, belief_3 and

Table 3
Factor analysis.

Indicator	Factor 1 - Fear	Factor 2 - Belief
I1. I believe there is a probability to get affected by COVID-19 through socialization	0.41	
I2. I am worried I might get infected if I travel	0.65	
I3. I will panic if I/friends/family travel during the pandemic	0.61	
I4. I believe masks can prevent the spread of COVID-19		0.51
I5: I believe if more people followed rules, the society would be a better place		0.41
I6: I believe vaccination can prevent us from being affected by COVID-19		0.49
I7: I am constantly following all the news updates regarding the virus.		0.53
Cronbach's alpha	0.51	0.644
KMO measure for sampling adequacy	0.695	
Bartlett's Test of Sphericity	Chi squared	755.98
	df	91
	significance	0.00

belief_4 respectively. All the indicators are observed to be positively related to the corresponding latent variables, evident from the positive loading. The last row of Table 4 presents the Cronbach's alpha value which is a commonly employed statistic to check the efficacy of factor analysis. The Cronbach's alphas were observed to be 0.51 and 0.644, and these values were considered satisfactory. The correlation among the items was inspected to understand the convergent validity and apart from one item, the rest within the same scale had correlation above 0.35, which is considered sufficient for convergent validity. Similarly, the correlations among the items of competing scales were less, indicating a satisfactory discriminant validity. KMO measure was found to be 0.695 and the Bartletts test of Sphericity was found to be significant, rendering the factor structure satisfactory for further analysis. The same latent structure as elicited by the factor analysis was used in the measurement model of the Integrated Choice and Latent Variable (ICLV) structure.

4.2. Integrated choice and latent variable (ICLV) model

Integrated Choice and Latent Variable (ICLV) model provides a theoretical extension to the conventional discrete choice models, explicitly capturing the effect of latent variables in the choice making process. It consists of two different components- the discrete choice part and the latent variable part. The discrete choice part models the choice of an individual using the latent utility that he/she derives from the choice. The latent variable part has two further components- a structural equation part defining the structural relationships between the latent variables and the observed variables (or other latent variables) and a measurement equation part explaining the measurement of latent variables through indicators.

Mathematically, the ICLV model can be represented as given below.

$$U = A_0 + A_1 X_{n1} + A_2 X_{n2} + A_3 X_n^* + \varepsilon_n \quad (1)$$

$$X_n^* = B_0 + B_1 X_{n2} + B_2 X_{n3} + \sigma \vartheta_n \quad (2)$$

$$i_n = C_0 + C_1 X_n^* + \delta \varphi_n \quad (3)$$

here, equation (1) represents the utility equation of the discrete choice part. In equation (1), U represents the probabilistic utility vector of an individual for the alternatives, A_0 represents the vector of intercept, A_1 represents the matrix of coefficients for the explanatory variables entering only the choice part X_{n1}, A_2 represents the matrix of coefficients for the variables entering both the utility model and the structural equation X_{n2}, and A_3 represents the coefficient matrix of the latent variables X_n^*. ε represents the vector of error terms which are i.i.d gumbel variables. In equation (2), B_0 represents the vector of constants in the structural equation, and B_1 represents the coefficients of the variables X_{n2}, which enter both the utility and the structural model of the latent variables. B_2 represents the coefficient vector of variables X_{n3}, which only enter the structural equation of the latent variable. σ represents the vector of variances of the error term ϑ, which is considered multivariate normal in this study. Equation (3) represents the measurement equation which explains the variance of the indicator variables i_n , using the corresponding latent variable x_n^*. C_0 represents the vector of constants and C_1 represents the coefficients of the latent variables X_n^*. δ represents the vector of variances for the multivariate ordered probit error vector φ. As the choice variable considered (willingness of individuals) was measured on a likert scale, an ordered logit kernel was used to capture the utility of each level on the likert scale. In the ordered model, the levels are represented as.

$$P(j_i) = F(U - \tau_i) - F(U - \tau_{i-1})$$

where P (j_i) is the probability of individual choosing level j_i, and τ_i and τ_{i-1} are thresholds for the levels and parameters to be estimated. The willingness of individuals to choose a non-shared mode such as 2-wheeler, 4-wheeler or ride hailing services, instead of a shared mode such as public transportation was measured on a likert scale. The scale consisted of five levels: least willing – 1, less willing – 2, neutral – 3, more willing – 4, most willing – 5. These levels were considered to be discrete because of which the ordered logit kernel was employed in modelling the discrete choice. Further, a hybrid structure was adopted to understand the marginal impact of latent variables upon the dependent variable.

The description of explanatory variables employed in all the three studies is given in Table 4.

In the following results, in the measurement equation section, belief-2, belief-3 and belief-4 represent the indicators for the latent variable belief. Similarly, fear-2 and fear-3 represent the indicators of the latent variable fear. For the purpose of identification, the parameter values of belief-1 for the latent variable belief and fear-1 for the latent variable fear are set to unity. Biogeme (Bierlaire, 2020) presented a robust statistical package in python to evaluate the maximum likelihoods of complex models such as ICLV, aiding the current study.

Table 4.
Nature of demographic variables in the analysis.

Name	Variable value = 0	Variable value = 1
Gender	Female	Male
Regionality	Rural	Urban/semi-urban
Occupation category-1	Students, business, free lancers	Government/private sector employees
Cov_fam	No history of COVID-19 infection in family	Presence of COVID-19 infection history in family
Cov_per	No history of self-infection of COVID-19	history of self-infection of COVID-19
Indicators in choice model	Levels 1,2 and 3	Levels 4 and 5
Age	Continuous	
Income		

5. Results and discussion

5.1. Willingness to choose a non-shared mode instead of a shared mode in a post vaccinated scenario

Figure 1 describes the willingness of individuals to choose a non-shared mode in a fully vaccinated scenario post-COVID-19. Across the set of respondents, it can be fairly assumed that the willingness to choose a non-shared mode is really high, while considerable number of respondents also exist who are inclined towards other competing modes of transportation.

The measurement equation for all the models is specified according to the output of factor analysis (Table 3). The error terms defining the indicator variables in vector φ_n are assumed to be independent and identically distributed gaussian variables. For identification purpose, the intercept and parameter of any one indicator variable for each latent factor is set to unity.

In the structural equation part of the latent variable models, fear is assumed to be influenced by the age of the individuals, along with the regionality of the individuals i.e., whether the individuals belong to an urban/semi-urban regionality or to a rural region. Similarly, the belief of individuals is assumed to be dependent on the monthly income of the individuals along with the gender of the respondents. These were derived by testing all the explanatory socio demographic and latent variables along with their interactions. The error terms of the structural model are assumed to be i.i.d gaussian variables.

5.1.1. Mandatory trips:

Mandatory trips included the trips made to offices for working people and to educational institutions such as schools and colleges for students. In Table 5, the positive parameter of age in the structural equation suggests an increase in fear as the age of the respondent

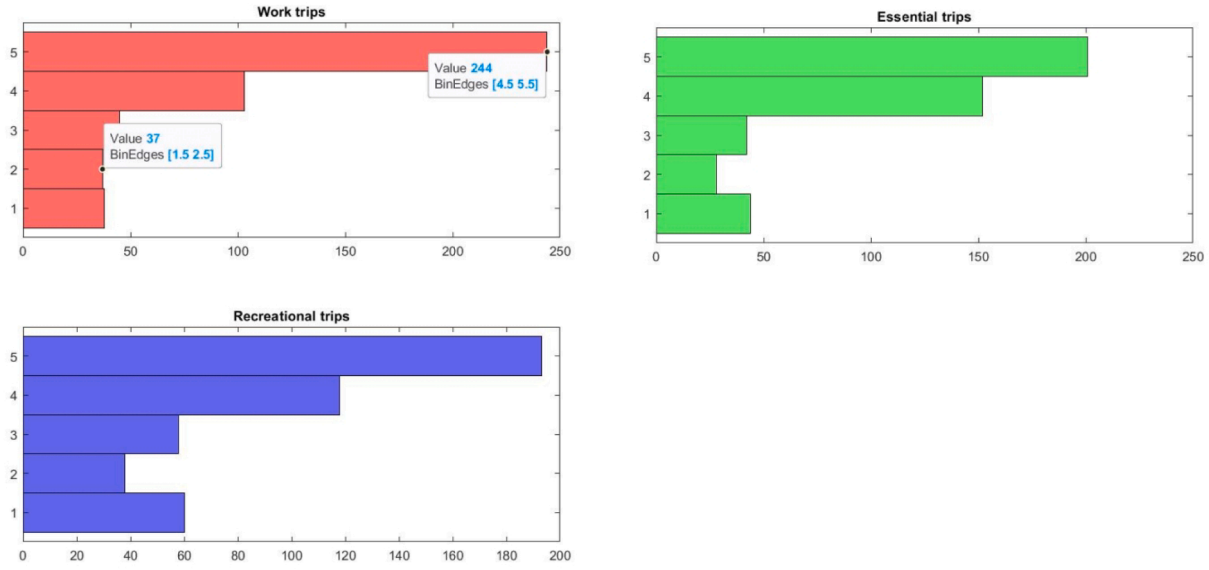

Fig. 1. Willingness of respondents to choose a non-shared mode.

Table 5
Parameter estimates for mandatory trips.

Name		Value	Rob.p-value
Choice model			
ASC		*0.627*	*0.00*
*Belief*cov_pers*		*−0.48*	*0.06*
cov_fam		*0.863*	*0.00*
Fear		*0.191*	*0.04*
*I11 * personal vehicle ownership*		*0.423*	*0.03*
ch_pv[##]		*0.388*	*0.04*
Measurement equation			
Belief	*belief-2*	*1.23*	*0.00*
	belief-3	*0.942*	*0.00*
	belief-4	*0.81*	*0.00*
Fear	*fear-2*	*0.479*	*0.00*
	fear-3	*0.497*	*0.00*
Structural equation			
Fear	*Age*	*0.353*	*0.00*
	Regionality	*0.665*	*0.00*
Belief	*Gender*	*0.493*	*0.00*
	Income	*0.138*	*0.00*
Final likelihood	−4813.28		
Adjusted Rho squared	0.621		

[##] where ch_pv is equal to 1 if the mode choice of the respondent in pre-COVID-19 time was personal vehicle and 0 if the mode choice was not personal vehicle (i.e., public transit, shared modes).

increases. The respondents of urban/semi-urban regionality are observed to have a positive impact on the fear towards contracting the virus compared to the rural respondents. Further, male respondents are observed to have a greater belief towards the COVID-19 protocols compared with female respondents, as suggested by the positive and significant parameter of gender. Similarly, as the income of respondents increases, it is observed that the belief towards preventive measures increases, as inferred from the positive and significant parameter. In line with the output of factor analysis, the parameter values of the measurement equations for the two latent variables belief and fear are positive with significant p-values.

From Table 5, the willingness to choose a non-shared mode instead of a shared mode for mandatory trips was observed to be influenced by:

i. Interaction between the belief of the individuals (latent) and self-history of COVID-19 infection: The willingness to choose non-shared transportation modes for mandatory trips in a post vaccinated scenario reduced for respondents who were already affected by COVID-19, as their belief in preventive steps toward preventing COVID-19 increased. This belief did not have any impact on non-infected respondents. This could be an indication of the greater influence of this belief factor among persons who were infected with virus compared with people who were not infected with virus.
ii. History of COVID-19 infection in family: The willingness was further observed to increase if there was a history of COVID-19 infection in the respondent's family (cov_fam). This meant that people who were having a history of COVID-19 infection in their family were more willing to choose a non-shared mode for their mandatory trip compared with people who did not have family member who was infected.
iii. Fear of the respondent (latent): Fear had a positive and significant effect on willingness to choose non-shared transit. Hence, people who were scared of contracting the virus were more willing to choose non-shared modes compared with shared modes for their daily mandatory trips.
iv. Interaction between Ind-11 and status of personal vehicle ownership: Further, people who own personal vehicles, and people who think that personal vehicles are a sign of prosperity, were more willing to choose non-shared transport options compared with shared modes. The latter impact was evident from the positive and significant parameter of the interaction term 'I11 * personal vehicle ownership, where the indicator, to be used in the choice model, was converted into a binary variable, considering levels willing and most willing to be 1, and all other to be 0.
v. The respondent's mode choice in the pre-COVID-19 times for mandatory trips: Finally, the people who chose personal vehicles in the pre-COVID-19 time were more willing to choose a non-shared mode of transport in the post vaccinated stage compared with people who did not chose personal vehicles.

5.1.2. *Essential trips*

The essential trips included the trips made for the purchase of essential goods such as milk, vegetables and medicine. Table 6 presents the willingness to choose a non-shared mode for essential trips which was observed to be influenced by:

i. The interaction between the belief of the individuals (latent) and self-history of COVID-19 infection: the willingness to choose non-

Table 6
Parameter estimates for essential trips.

Name		Value	Rob. P-value
Choice model			
ASC		*0.87*	*0*
*Belief * cov_pers*		*−0.50*	*0.08*
cov_fam		*0.8*	*0*
Ch_pv		*0.35*	*0.04*
Measurement equation			
Belief	*belief-2*	*1.24*	*0*
	belief-3	*0.939*	*0*
	belief-4	*0.811*	*0*
Fear	*fear-3*	*0.478*	*0*
	fear-4	*0.499*	*0*
Structural equation			
Fear			
	Age	*0.357*	
	0		
	Regionality	*0.698*	*0*
Belief			
	Gender	*0.508*	*0*
	Income	*0.135*	*0*
Final likelihood	−4847.758		
Adjusted Rho squared	0.838		

shared modes for essential trips in a post vaccinated scenario is observed to be negatively influenced by the belief of individuals in COVID-19 preventive measures if he/she has a history of COVID-19 infection. This result was similar to that of the results obtained for mandatory trips

ii. The history of COVID-19 in family: the presence of history of COVID-19 infection in the family of respondents is understood to have a positive impact on the willingness to choose a non-shared mode of transportation.

iii. Pre-COVID-19 mode choice of the respondents: Similar to mandatory trips, the influence of pre-COVID 19 mode choice is observed to be positive, implying a higher willingness for non-shared mode if the past mode choice was non-shared as well

5.1.3. Recreational trips

The recreational trips included the trips made for recreational purposes such as shopping, movies, malls etc. For recreational trips, as observed in Table 7, the willingness to choose a non-shared mode was observed to be impacted by:

i. The respondent's belief towards the sanitization measures (Ind-3): the willingness to choose a non-shared mode for recreational trips in a post vaccinated scenario is observed to be positively influenced by the respondent's belief towards sanitization measures.

ii. The history of COVID-19 in the family of the respondent: Higher willingness to choose non-shared modes can be observed for respondents who had a history of COVID-19 infection in their family.

iii. Interaction terms of fear and regionality: For urban/semi-urban respondents as the fear of getting infected increases, they are more willing to choose a non-shared mode as evident by the positive and significant impact of the interaction variable.

iv. interaction term of indicator 11 (I believe owning and using private modes is a sign of prosperity compared to non-motorised transport and public transport) and the personal vehicle ownership: People who own a personal vehicle and think it to be a sign of prosperity, are observed to have an inclination towards choosing a non-shared mode for recreational trips.

Table 7
Parameter estimates for recreational trips.

Name		Value	Rob. P-value
Choice model			
Ind-3		*0.36*	*0.01*
cov_fam		*0.742*	*0*
*Fear * Regionality*		*0.27*	*0*
*Ind-11 * personal vehicle ownership*		*0.46*	*0.02*
Measurement equation			
Belief	*belief-2*	*1.24*	*0*
	belief-3	*0.943*	*0*
	belief-4	*0.807*	*0*
Fear	*fear-2*	*0.474*	*0*
	fear-3	*0.492*	*0*
Structural equation			
Fear	*Age*	*0.358*	*0*
	Regionality	*0.647*	*0*
Belief	*Gender*	*0.518*	*0*
	Income	*0.13*	*0*
Final likelihood	−4887.256		
Adjusted Rho squared	0.84		

5.2. Willingness to choose public transport under different COVID-19 preventive measures

In the stated preference experiment, eight different levels were chosen based on two levels of three policy variables corresponding to safety perception during COVID-19 – sanitization, personal vaccination status and social distancing as presented in Table 8, where 0 represents the scenario where the specific protocol was not implemented and 1 represents its execution.

The willingness to choose public transportation was measured using a likert scale, varying from most willing to choose public transportation in the scenario (5), to least willing (1). The respondents were asked to state their willingness in all the 8 scenarios, leading to 3736 individual responses from 467 respondents.

The preventive measures were presented to the respondent as a stated preference experiment (Table 8) and were incorporated in the ICLV framework as explanatory variables of the latent safety perception (structural equation). Further, the indicator corresponding to this safety perception was a likert scale variable that measured the extent of perceived safety for each of the different combinations of the variables in the stated preference experiment. For identification purpose, the parameter value in the measurement equation is set to unity. Further, in the structural equation, age entered as an explanatory variable along with the stated preference variables.

In Table 9, perception of safety of individuals is observed to be influenced positively by execution of sanitization in the public transport, social distancing, the status of personal vaccination. Further, the age of the respondent had a negative impact on the safety perception. This implied that older people perceived public transport to be lesser safe compared with younger people.

The willingness to choose public transportation is affected by:

i. The perception of safety of the respondents in a positive direction, explaining that as people perceive higher amount of safety, they are more willing to choose public transportation.

Table 8
Levels in stated preference experiment.

Scenario	Personal vaccination status	Sanitization of vehicle	Social distancing in vehicle
1	0	0	0
2	1	0	0
3	0	1	0
4	0	0	1
5	1	1	0
6	1	0	1
7	0	1	1
8	1	1	1

Table 9
Parameter estimates for stated preference experiment.

Name	Value	Rob. p-value
Choice model		
ASC	*0.25*	*0*
Gender	*0.08*	*0.35*
Occupation category 1	*0.16*	*0.03*
Safety	*1.74*	*0*
Regionality	*−0.07*	*0.44*
Correlation	*0.79*	*0*
Structural equation		
Safety - age	*−0.05*	*0.1*
constant	*−1.57*	*0*
Safety - sanitization	*0.69*	*0*
Safety – social distancing	*0.75*	*0*
Safety - vaccination	*0.90*	*0*
Final likelihood	*−9682.404*	
Adjusted Rho-square	*0.414*	

ii. Male respondents are observed to be more willing to use public transportation compared with females.
iii. Employees of government and private sector (occupation category 1) are observed to have an inclination towards usage of public transport as evident from the positive coefficient.
iv. Urban people are observed to be not willing to use public transportation, as inferred from the negative and significant parameter.

5.2.1. Willingness to choose Non-Motorised transport (NMT) in a post vaccinated stage

Non-motorised transport promotes an active lifestyle. For short trips involving a distance of less than 1.5 kms, the willingness of individuals to choose non-motorised transport in a fully vaccinated stage is given in Table 10, and is observed to be influenced by:

i. The belief of the respondents towards COVID-19 preventive measures: The willingness of respondents to use non-motorised transport for short trips in a post vaccinated scenario is influenced by the belief of individuals in a positive and significant manner, and this implied an increased willingness among people to choose NMT with an increase in their belief towards the COVID-19 preventive measures

Table 10
Parameter estimates for Non-Motorised transport.

Name		Value	Rob. p-value
Choice Model			
ASC		*−0.16*	*0.08*
Age		*0.153*	*0.04*
Belief		*0.542*	*0*
Fear		*−0.274*	*0.01*
Ind-12		*0.475*	*0.01*
Regionality		*0.458*	*0.02*
Measurement equation			
Belief	*belief-2*	*1.24*	*0*
	belief-3	*0.94*	*0*
	belief-4	*0.81*	*0*
Fear	*fear-2*	*0.48*	*0*
	fear-3	*0.50*	*0*
Structural equation			
Fear			
	Age	*0.35*	*0*
	Regionality	*0.62*	*0*
Belief	Gender	*0.52*	*0*
	Income	*0.13*	*0*
Final likelihood	−4858.252		
Adjusted Rho squared	0.0212		

ii. Fear of the respondents: Respondents who are scared of infection of virus are not willing to choose non-motorised transport as is evident from its negative parameter value
iii. Ind-12: Indicator-12 (Table 2) had a positive impact on the willingness. Respondents who think NMT reduces pollution are willing to choose active modes such as walking and cycling
iv. The regionality of the respondents: urban/semi-urban dwellers are observed to have a higher inclination towards non-motorised transport.
v. The age of the respondents: As age increases, people were more willing to choose non-motorised modes such as walk or cycling

6. Conclusions

COVID-19 pandemic and subsequent measures to curtail its spread are understood to have a significant long-term behavioural implication on mobility and travel. People are afraid to use public transportation modes that are meant for mass transportation. Further, many people have severe doubts regarding the efficacy of vaccination and other COVID-19 preventive measures. This explains the rising attractiveness of personal vehicles as daily modes of transport. The diminished usage of public transportation and non-motorised transport needs to be understood and counteracted with COVID-19 specific policy measures that revive the sense of safe, secure, eco-friendly and pocket friendly travel among the public.

The current study incorporates a hybrid choice framework, to understand the intended mode choice behaviour of individuals in a post vaccinated scenario for three different trip types- mandatory trips to work places and educational institutions, essential trips for buying vegetables, medicine etc and recreational trips which include shopping, movies etc. Further, a stated preference dataset is used to understand the willingness of individuals to use public transportation such as buses and metro under different scenarios of COVID-19 protocol execution. These included the mandate of vaccination, social distancing and sanitization after each trip. Finally, the willingness to choose non-motorised transport for short trips was modelled using these latent factors.

The fear of being infected by the virus, along with the belief towards the COVID-19 preventive measures were observed to be dominant latent factors, impacting the willingness of individuals to choose non-shared modes such as personal car or two-wheeler. Belief is observed to negatively impact the willingness to choose non-shared modes for work and essential trips. Further, its interaction with the dummy variable -self history of COVID-19 infection - explains the psycho-attitudinal effect of the pandemic on the people having a history of infection. The sense of insecurity developed by the misinformation spread about the virus itself (Burel, Farrell and Alani, 2021; Torpan et al., 2021; Sharevski et al., 2022), slows down the pace of fight against the pandemic. Spreading awareness regarding the virus should be of a primary concern to the authorities, where penetration of facts into people aids in the collective participation of public in the fight against pandemic.

Vaccination of people against COVID-19 is a major step to unlock a safer world. But the low belief of people towards the efficacy of vaccination slows down the process which is reported in many places across the world (Bartsch et al., 2020; Chakraborty et al., 2021; Chandani et al., 2021; Machingaidze and Wiysonge, 2021; Li, Chen and Rao, 2022; Machingaidze and Wiysonge, 2021). At the time of the data acquisition, a major proportion of the population has been vaccinated, implying an increased awareness about the efficacy of vaccine among the people. But the continual strides of governments have been in vain a some parts of India (Samanta et al., 2022). A detailed understanding of vaccination, its effects and efficacy has to be advertised among people. It could be similar to the awareness campaigns and drives created for usage of masks and social distancing so that a common consensus be created among all the sections of the society.

Fear of contracting the virus is observed to be another prominent factor impacting the mode choice decisions of individuals. Fear

increased the willingness of respondents to choose a non-shared mode for work trips and recreational trips. Fear appears to be dominant even after the effects of pandemic are observed to be receding. Due to the rapid increase in the cases and hike in the fatality rate, the fear component played a major role in every decision the individuals took towards their life in general (Menzies and Menzies, 2020). Proper mechanisms should be introduced to reduce and counteract this fear. Otherwise, this may lead to an unhealthy lifestyle that may affect both the work life and family life of the population. Psychological wellness centres should be set up to provide counselling to necessary people. Necessary steps must be considered for the purpose of behavioural intervention, such that the execution of policy measures is effective at the microscopic level (Zhang, Hayashi and Frank, 2021).

The perception of safety among respondents significantly affects their choice of public transportation. This safety is a function of different factors including the maintenance of social distancing, scheduled sanitization and mandatory vaccination of passengers, as observed in Table 9. This shows the increased responsibility of the concerned public transportation authorities, towards execution of these measures in a strict sense, to ensure safe travel for the passengers. Further, online payment and ticketing systems can aid in a virtual check of these measures by a controlled app integration. This step can also ensure an effective fleet management, by eliciting the demand of passengers. As revealed by studies (Aaditya and Rahul, 2021a), people are willing to spend more money/time to travel in public transport if effective measures to curtail the spread are executed. As peoples inclination towards work from home is volatile as evident from many studies (Beck et al., 2020; Aaditya and Rahul, 2021b; Mouratidis and Papagiannakis, 2021), instilling confidence among public transport users might reinforce the belief in the community of employees who use public transit for daily commute. At the scenario where 81 % of public transit services reported no ridership at all (|| Impact of COVID-19 on Indian bus operators | UITP ||, 2022), these counteractive measures aid in taking the crumbling public transportation systems forward, as a decreased ridership might affect the overall performance and economy. As a part of restructuring, the country's measures of sanitization, social distancing and crowd management have been fairly effective to pull the crowd back towards using public transportation, which shows the affinity of public towards public transportation. This must be further encouraged with a resilient system, resistant enough to tackle future waves of pandemic and other paradigm shift problems.

The current study is constrained by the sample size, where the reach of the questionnaire was not sufficient to generalize the results about the pandemic on a global scale. Further, as the pandemic advanced, the infection rate, the local conditions and other factors, divided the nature of people into risk taking or risk aversive, in all aspects, which is unaccounted for in this study. This can be considered as a future scope which has a potential to study upon.

Declaration of Competing 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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