Post COVID-19 behavioural changes in First-Last Mile travel and perception on service quality of public transport

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Abstract: This study examines the impact of COVID-19 on commuters' travel behavior and satisfaction with public transport in New Delhi, India during post COVID-19. A CAPI-based survey was conducted in December 2021 among 483 transit users who traveled pre- and post-COVID-19. The study compares changes in trip frequency, access-egress mode choices and related travel time, and level of satisfaction with respect to nine service quality attributes. Multiple linear regression technique was modeled to identify the significant attributes that have affected overall satisfaction of commuters. Key findings include: i) shift towards higher mobility-based or safer access-egress modes and longer access-egress travel times, and ii) substantial (one-fifth) increase in mean satisfaction level of service quality attributes, iii) identification of attributes like alighting from the vehicle, and cleanliness – at and around stop/stations as the most and least sensitive attributes respectively. These insights highlight areas for service improvements to enhance future transit resilience.

Keywords: Covid-19, Public Transport, Service Quality, Travel Behaviour

1 INTRODUCTION

COVID-19 caused severe health impacts and catastrophic human deaths. Social or direct contact with the infected persons, near proximity of the contaminated objects and their surroundings were reported as the primary reasons for the spread of COVID-19. Public Transport (PT) was recognized as the main contributor to the spread of this infection as PT is a high public utilization service, gathers large crowds, and works as an interactive service (Gkiotsalitis and Cats 2021; Subbarao and Kadali 2022). With such beliefs many nations imposed partial or complete travel and social restrictions on the use of PT during COVID-19. India also enforced phase-wise nationwide lockdowns and unlock measures during March 25, 2020, to July 31, 2021, and thereafter state/city wide partial restrictions were imposed as per rate of growth in confirmed cases locally (Velmurugan et al. 2023). These measures increased work from home, study through e-mode, shop online and reduced travel significantly, except the travel for essential services and needs. The psychological fear of infection while traveling (Gutiérrez et al. 2021; Chuenyindee et al. 2022) even impacted the travel behavior and habits of commuters, and their satisfaction with the transit services (Dong et al. 2021; Khaddar and Fatmi 2021; Esmailpour et al. 2022) even after resumption of the full PT services post-COVID.

The COVID-19 pandemic had far-reaching implications on commuters' travel behaviors, which in turn had significantly affected PT performance (Deb and Hinge 2023). In general, the period saw major change in transport modal share, particularly decline in PT ridership and increase in share of other travel modes across European, American, and Asian cities (De Vos 2020; Kanda and Kivimaa 2020; Eisenmann et al. 2021; Zhang et al. 2021a; Liu

et al. 2022). For example, the PT ridership in USA was 29 percent compared to the pre COVID-19 period until March 2023 (Burris et al. 2023). PT in Guwahati, India was reported recovering from the shock post-COVID (Deb and Hinge 2023). Notably, due to the drop in ridership the revenue for PT operators dipped, while other expenses such as employee salaries, maintenance, and service quality delivery remained as recurring expenses. The decline in transit ridership can be primarily attributed to shifts in commuters' travel behavior, which might get influenced by governmental regulations or restrictions imposed on PT services, as well as passengers' concern regarding safety while traveling on PT. More than 20 percent of PT commuters from European (Nikolaidou et al. 2023) and around 45 percent of PT commuters from American cities (Burris et al. 2023) left the system post COVID-19. Around, 61 percent of PT commuters from Ethiopian cities wished not to travel with PT again post COVID-19 (Moges and Mitiku 2023). They had mentioned several reasons for leaving the systems such as unavailability of service capacities (operation hours, service frequencies, etc.), government restrictions, fear of not meeting the expected sanitary and cleanliness measure, unavailability or limited availability of access-egress travel (environment, modes, and time), and lower delivery of service quality (Esmailpour et al. 2022; Shimamoto and Kusubaru 2023; Moges and Mitiku 2023; Huang et al. 2024). Long et al. (2023) reported recovery phase in demand for PT in UK and observed that older people and some ethnic groups had not returned to transit systems. They reasoned changes in their travel patterns, risk of infection, and availability of alternative services for this behaviour. Passengers from extreme ends of income profile (higher earnings and unemployed) tended to travel higher during COVID-19 as compared to passengers who earned in-between (Mayo et al. 2021). These behavioural and preferential changes may have operational and developmental consequences for PT systems. This may further lead to financial downside, ineffective policies and decision making related to PT services. PT service providers or operators need to learn from the new travel patterns and behaviour of the commuters and to adjust their service quality delivery post COVID-19 accordingly. This can also prepare them to meet changes in demand if a similar pandemic hits in future.

Few researchers had studied the short and long-term effects on commuters' travel behavior (de Haas et al. 2020; Przybylowski et al. 2021; Thomas et al. 2021; Kellermann et al. 2022). The impact was visible in all three legs of the travel i.e., access (First mile), egress (Last mile), and primary travel, with no surety of it getting normal after resumption of services (Zhang et al. 2021a). COVID-19 is believed to have caused long term disruptions and deterioration in PT service delivery, especially for first mile and last mile travel and mode choices (Liu et al. 2024). Negm and El-Geneidy (2024) concluded that improving PT accessibility had become challenging post-COVID-19. Unavailability of access-egress travel modes, change in access-egress path due to containment related travel restrictions in between the passengers' origin or destination, hike in access-egress travel fare due to monopoly or unavailability of access-egress travel choices, fear of infections while using the access-egress modes to reach the PT stop/station, etc. might have influenced the passengers' access-egress travel behaviour during as well as post-COVID-19. This change in behaviour influenced passengers' decision to choose the PT for their primary trip. Khursheed and Kidwai (2022) observed a change in access-egress travel time and distance to PT during COVID-19 due to the limited availability of the access modes in New Delhi, India. In their another study, Khursheed and Ahmad Kidwai (2022) observed that the in-accessibility and unavailability of access-egress travel modes negatively impacted several performance indicators of MRT during the COVID-19 period. Few had examined the accessibility of PT systems focusing on the specific passengers' groups. In Ohio (USA), Liu et al. (2023) observed increase in access travel time of physically disabled passenger groups post COVID-19. Similarly, the accessibility of the low earnings passengers was the most affected than others post COVID-19 in three Canadian cities

(Negm and El-Geneidy 2024).

The use of PT also depends upon the level of service quality (attractiveness within the PT system) and accessibility (attractiveness outside of the PT system) provided to the passengers (Papaioannou and Martinez 2015; Singer et al. 2023). These two aspects impact the passengers' preference for the PT system over other transport modes. Accessibility to PT refers to how easy it is for passengers, regardless of their physical abilities, age, gender, income, or education, to reach a PT stop/station, using the quickest and most affordable transport options available in the vicinity (El-Geneidy et al. 2016; Litman 2022). Once a passenger arrives at the stop/station, passengers' expectations with the PT service quality and their satisfaction with the offered service quality play a role in their reuse of the PT system. Thus, passengers' satisfaction is a psychological measure that is used to assess the shortcomings in the service quality of PT systems. PT service quality can be defined based on functional, operational, and infrastructural criteria (Verma and Rastogi 2022). An accessible PT and service quality offered in consonance with the passengers' satisfaction level are found to be attractive and most likely to be used by them during and post COVID-19 era (Dong et al. 2021; Wang and Gao 2022). Few studies looked at passengers' satisfaction with PT service quality and shift in priorities during the COVID-19 period (Zhang et al. 2021b). Esmailpour et al. (2022) found a shift from system infrastructural (information delivery, convenience, and reliability) to functional (comfort) attributes during COVID-19 and observed an increase in the satisfaction level of bus passengers. Aghabayk et al. (2021) too observed an increase in the comfort value for passengers in Tehran city of Iran. Dong et al. (2021) reported that passengers gave higher importance to communication of COVID-19 related information inside the transit station, at stops, in access and egress areas, and inside vehicle coaches, while travelling. Khaddar and Fatmi (2021) combined passenger satisfaction by relating with their travel behavior and found that the passengers travelling for non-mandatory trips were highly satisfied during COVID-19 period. Sun et al. (2022) studied change in satisfaction of low-income passengers of bus transit considering socioeconomic, travel, and psychological attributes. They observed a change in priorities regarding quality attributes during COVID-19. Such changes were different for different transport modes (Zafri et al. 2022; Zhou et al. 2023). *However, the worldwide studies focusing on these aspects were mostly conducted during COVID-19*.

This indicates that the passengers' travel behavior and subsequent expectations from the PT systems have changed from pre to during and then post COVID-19 when the new normal began. **Table 1** lists studies primarily focused on passenger satisfaction with the PT system in context of COVID-19. Three inferences can be drawn from this information. First, most of the analysis is conducted on pre and during COVID-19 travel data and hence those do not project the realistic satisfaction level of the passenger post COVID-19. Second, almost all analysis except (Deb and Hinge 2023) had used a general list of service quality criteria or sub-attributes. This included information which in general is not affected by COVID-19. Third, earlier studies had focused on contacting PT passengers through social media campaigns i.e. Facebook, LinkedIn, etc.; local available online platforms; public gathering locations, etc. using snowball or random sampling techniques. These platforms were preferred due to restraints in travel. Targeting respondents through these approaches usually result in biased response (Verma and Rastogi 2023).

The discussion above underscores the challenges that COVID-19 presented for PT and commuters, while also emphasizing the need for PT service providers or operators to gain insights from passengers' travel patterns and expectations in the new normal. This understanding will give insight to PT operator to cater services commensurable to the passengers needs and preparedness if similar event hits in future. Further it clearly highlights that the prolonged change in travel behavior of commuters during COVID-19 probably got

transformed in to travel habit impacting the primary and access-egress travel choices, as well as the importance of and satisfaction with the operational, functional, and infrastructural criteria. The discussion also highlights the shift in quality attributes that passengers gave weight to as compared to others. *As not all quality attributes were impacted during COVID-19, it brought the importance of identifying the key attributes which should be considered for improvisation.* The authors noted that the studies have not reported the attributes which were potentially affected due to COVID-19 and how these changes have resulted in a change in their satisfaction level as well as how access-egress travel behaviour changed post COVID-19. With these brief contexts, this paper aims to present the changes in the following under the impact of COVID-19:

- Mode choices related to first mile and last mile connectivity to PT.
- Trip frequency and travel time change between mostly used and alternate chosen modes.
- Satisfaction with service quality attributes being impacted by COVID-19.

To meet the above goals, the present study utilizes a questionnaire-based survey data collected on station in Dec 2021 from New Delhi PT (DTC Bus as well as DMRC Metro) commuters when the lockdown was lifted, travel restrictions were partially relaxed, and PT services were resumed with limited service and capacity restrictions within the city.

The manuscript is presented as follows. **Section 2** identifies the attributes which are potentially affected by COVID-19. **Section 3** presents survey methodology and sampling information. **Section 4** and **5** present the analysis related to the travel behavior of passengers and their satisfaction. **Section 6** models the passengers' satisfaction data. **Section 7** and **8** discuss the results and explore the policy implications, respectively. In the end, **section 9** concludes the study.

Table 1 Studies exploring Passengers' Access-Egress Travel and Satisfaction with Service Quality Attributes in context of COVID-19

Location – Researchers (Year)	**COVID-19 Context**	**Survey Information**				**Service Quality Criteria or Sub-Attributes Considered**	**Focus on Post COVID-19 & Attributes screened based on COVID-19 Impact**
		Period	**Sampling Technique**	**Mode***	**Size**		
This Study	Change in passengers' access-egress travel behaviour and satisfaction with quality attributes post COVID-19.	Dec 2021	Random Sampling at Station	CAPI	483	Seat Availability, Crowding, Boarding-Alighting, Service Frequency, Ticketing Service, Cleanliness, Overall Ambience, Overall Satisfaction	Both
Taiwan, China - Hsieh (2023)	Change in attributes priority among passengers post-COVID-19.	July 20-24th, 2020	Random Sampling at Station	PAPI	204	Air conditioning, Social Distancing, Sanitization, Boarding-Alighting, Accessibility, Speed, Punctuality, Interconnectivity, Noise and Air Pollution, Staff Personnel, Information Availability, Ticketing Service, Cleanliness, Comfort, Fare Affordability	Not Considered
Hong Kong, China - He et al. (2023)	Change in satisfaction and travel behaviour for several transport	June 2020	-	CAWI	1119	Overall Satisfaction	Not Considered

	modes (public, private, taxi, cycling, walk, etc.) in the region.						
Guwahati, India - Deb and Hinge (2023)	Change in passengers' priority to attributes from pre to during COVID-19.	Jan 2019 & Jan 2021	Mix of Snowball Sampling, Random Sampling at station and at crowd location	Mix of CAPI & CAWI	650 from pre and 470 during COVID-19	Cleanliness, Comfort, Social Distancing Measure, Staff Personnel, Seat Availability, Speed, Punctuality, Accessibility, Fare Affordability, Boarding-Alighting, Overall Satisfaction	Either
Campos dos Goytacazes, Brazil - Freitas et al. (2023)	Identification of influencing Service Quality Criteria	Jan – Apr, 2020	Mix of Random Sampling at Station, and Social Media Campaign	Mix of CAPI & CAWI	238 from CAWI and 61 from CAPI	Safety, Punctuality, Boarding-Alighting, Cleanliness, Airconditioning, Ticketing Service.	Not Considered
Tehran, Iran - Esmailpour et al. (2022)	Change in passengers' satisfaction with service quality attributes.	Oct - Nov 2019 & Nov 2020	Random Sampling Onboard and at-station, and Online Survey	CAPI in Pre & CAWI During COVID-19	709 from Pre & 820 from during COVID-19	Comfort, Safety, Reliability, Information Availability, Ease and Convenience, Fare Affordability.	Not Considered
Phillipins - Chuenyindee et al. (2022)	To explore the service quality related dimensions in light of COVID-19.	Aug-Oct, 2020	Online Platform	CAWI	564	Fare Affordability, Safety, Complaints Redresal, Overall Satisfaction	Not Considered
Taiyuan, Shanxi Province of	Explores the effects of income groups, and companion on	Dec 18 - 30, 2020 & May	Random Sampling at Public Crowd	-	930	Service Frequency, Punctuality, Social Distancing, Safety,	Either

China - Sun et al. (2022)	satisfaction before and post -COVID-19	18 -24, 2021	Location			Interconnectivity, Fare Affordability, Air-conditioning	
8 cities of China - Dong et al. (2021)	Investigating the passengers psychological and influencing factors during COVID-19 to re-use the PT.	Mar 14 - 15, 2020	Online Platform	CAWI	665	Social distancing, Information Delivery, Overall Satisfaction	Not Considered
Tiajin, China - Zhang et al. (2021b)	Studying the passengers psychological and satisfaction factors during COVID-19.	June 2020	Online Platform	CAWI	983	Cleanliness, Service Frequency, Safety, Information Availability, Overall Satisfaction	Not Considered

*CAPI: Computer-Assisted Personal Interview, PAPI: Paper-and-pen Assisted Personal Interview, CAWI: Computer Assisted Web Interviewing.

2 IDENTIFICATION OF COVID-19 IMPACTED SERVICE QUALITY ATTRIBUTES

Considering the contagious nature of COVID-19 virus and its spread through contact (passenger-passenger, passenger-infected surface of handrail, seat, ticketing, doors, glasses, etc.), the transport operators adopted various measures (limited seats, contactless ticketing, cleaning and disinfection, social distancing, and mandatory mask) to instill confidence in the passengers and to increase the ridership post-COVID-19. These resulted in changes in service quality offered, which was a new experience for the passengers. Nine primary service quality attributes have been identified which comprehensively define service quality of any transit system (Verma and Rastogi 2024). These are – comfort, ease and convenience, affordability, service frequency, travel time reliability, customer service, safety, personal security, and system infrastructure. The first three have functional, the next four have operational, and the last two have infrastructural value. Each primary attribute comprises of sub-attributes. A total of 31 sub-attributes were identified based on the literature survey and experts' opinion which comprehensively defined the transit service quality. These sub-attributes were further reviewed to identify the attributes which might potentially have been impacted due to COVID-19. It resulted in nine sub-attributes. These are:

- *Seat Availability*: Transit systems were operated with 50 percent seating capacity by marking alternate seat as 'X' indicating seating prohibition to maintain social distancing and proximity protocols. (Sun et al. 2022) has considered this attribute as a concern for bus passengers while traveling during COVID-19. As part of new normal, limited seat availability would be a satisfying experience but reduction in operational capacity without increase in frequency would be unsatisfying or inconvenient for the passengers.
- *Crowding:* Proximity or closeness of the co-passengers causing intrusion in the private space of a person can be defined as crowding at a place. It may happen inside a transit, at a stop or inside the station area. Crowding inside the vehicle got controlled during COVID-19 by reducing the operational capacity as mentioned above. Though a similar provision was made at a stop, it was difficult to enforce. The same was the case in the station area especially at platform or in concourse area. Passenger spacing at ticketing counter was managed through marking of circles using 6-ft social distancing. Considering the mixed condition of passengers' movement in defined areas it was expected that the satisfaction level of passengers would improve in some areas and may remain the same as pre-Covid-19 times for the other areas.
- *Boarding and Alighting*: During and post COVID-19, the transit service providers strictly enforced the use of rear and front door exclusively for passenger boarding and alighting respectively. This was used as a passenger interaction control measure along with other measures to contain infection as mentioned before. Boarding at a stop or platform was managed through marking of circles at floor to maintain social distance. However, all such measures got nullified post COVID-19 due to the use of high floor buses on some routes, the stopping pattern of a vehicle by driver at a stop, increase in passenger demand, etc. All of these had a potential impact on the passengers' satisfaction with respect to the ease and convenience during boarding-alighting.
- *Service Frequency*: Transit services were operated with reduced frequency during COVID-19 due to reduced demand. This reduced the transit operational capacity per hour. Post COVID-19 the passenger demand started increasing slowly but the frequency was not increased by the operators. This negatively affected the passengers waiting time. Nikolaidou et al. (2023) and Sun et al. (2022) have used this variable as passengers concern to understand their change in satisfaction level during the COVID-19.

- *Ticketing*: Ticketing is a customer service based sub-attribute. To avoid the risk of infection transmission, operators switched to contactless ticketing systems. This has led to a decline in the use of paper tickets and tokens, and an increase in the use of mobile apps and smart cards. However, this required installation of card reading devices (involving cost and time) and posed difficulty to the passengers not carrying a smartphone or mobile data plan or who were illiterate. This measure is expected to bring changes in passenger satisfaction in opposing directions based on the passengers' characteristics.
- *Cleanliness*: The service providers used measures like periodic disinfection, cleaning of vehicles/stops/station premises to reduce the likelihood of spreading the virus and instill confidence in making transit facility trustworthy in the eye of passengers (Musselwhite et al. 2020). This positively impacted the satisfaction level of the passengers. This aspect is examined as cleanliness:
    - *At stops/stations*: It include disinfection of benches, railings, and handrails of ramps, ticketing, and queuing areas, etc.
    - *In-vehicle*: It deals with indoor cleanliness of vehicles interior surfaces, seats, window glasses, handles, doors, etc.
- *Overall Ambience*: Overall ambience of transit is an outcome of various measures as mentioned above and includes information delivery, signages and boards to guide passengers. These measures may be looked at positively by the passengers, which may similarly impact on the satisfaction level.

3 STUDY AREA AND DATA COLLECTION

This section provides information on the study area selected for data collection and the survey methodology used.

3.1 Survey Design and Study Area

A questionnaire was designed to collect changes in perceptions of transit commuters' regarding PT service quality post the COVID-19 pandemic. The questionnaire comprised of three parts; first part collected respondents' general travel information pre/post COVID-19 period (before March 2019 and after November 2021); second part recorded the change in satisfaction level related to nine attributes; and third part gathered the personal information. The questionnaire was digitally configured for smartphone/tablet devices for sound visualization and transition of conditional questions to ease navigation. This was done as a contactless data collection measure. The questionnaire was pilot-tested, and improvisations to the questions were made before the main survey. Detailed information regarding survey questionnaire design during COVID-19 is available in (Verma and Rastogi 2023). PT commuters were the targeted respondents of the survey who had used the transit during pre/post COVID-19 period.

The whole New Delhi metropolitan region was mapped into assembly blocks, with the respective population information, in ArcGIS software. The survey locations were stratified based on the population density of the city. Subsequently, eleven survey locations comprising MRT interchanges and CBT Terminals according to the population density of the city were selected for the questionnaire survey. Delhi Metro stations and DTC Bus Terminals selected for the survey are shown in **Figure 1**. Enumerators having an education level graduate or higher were hired and trained before executing the survey. Hindi and English languages were used interchangeably as per respondents' convenience. Respondents were intercepted randomly at bus stops and metro stations. Computer Administered Personal Interview (CAPI) mode of survey was used for the face-to-face survey. An average of total 12 minutes was required to

complete a questionnaire. The survey was conducted during the second and third week of December 2021 (post 2nd COVID-19 wave) when travel restrictions were partially relaxed, PT begun operating in phase wise in New Delhi city, and people started using the city's PT. The survey was conducted on all days between 1000 to 1800 Hrs. The required sample size was estimated as suggested by (Dillman et al., 2014). 493 responses from passengers at 11 PT stops and stations were collected. After applying a logical check and response incompleteness, 483 pruned samples were screened for the analysis.

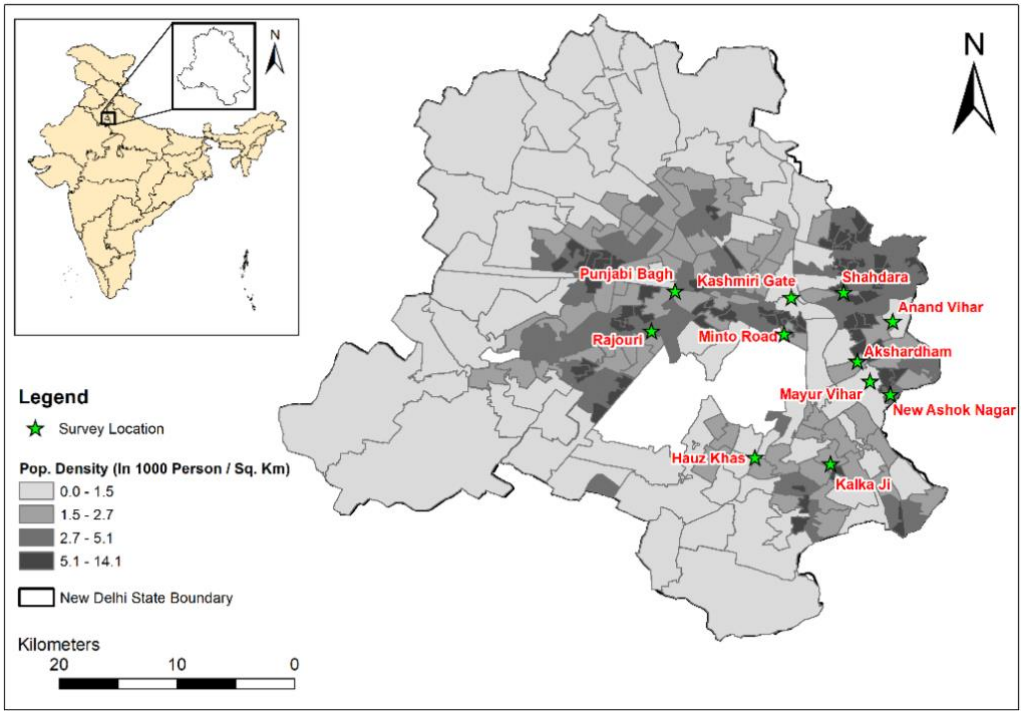

Figure 1. Questionnaire Survey Location in New Delhi Metropolitan City.

3.2 Respondents' Characteristics

Table 2 presents the respondents' socioeconomic and travel profile post COVID-19 period. The respondents' socioeconomic profile was observed to be in line with the one reported by (Suman et al. 2017). Close to 50 percent of the respondents in each socioeconomic category are graduates, work as supporting staff and at middle-level job positions, and earn 10K-25K per month. Notably, 75 percent of the respondents used PT for mandatory travel (work or education). Around 88 percent of passengers used PT service for short and long travel distances i.e., from 2 to 20 kilometers distance. The information on an alternate travel mode indicates that almost all the respondents are choice users. Trip frequency from respondents was asked to know their mobility particularly during the COVID-19 period and it was observed that 71 percent of the respondents stayed at home. Observations from the world show that around 56 percent of the commuters stayed at home and around 11 percent of those had not changed their travel frequency (Abdullah et al. 2020) during the COVID-19 period. Further, 9 percent of the respondents reported a reduction in their trip frequency, while 7 percent stated that their trips remained unchanged. Additionally, 13 percent of the respondents reported an increase in their trip frequency.

Table 2 Socioeconomic and Travel Characteristics of Respondents Post COVID-19

Dimension	Total Count = 483		Dimension	Total count = 483	
	Category	Sample/ Percent		Category	Sample/ Percent
Gender	Male	289/59.8	Trip Purpose	Work	208/43.1
	Female	193/40.0		Education	155/32.1
	Do not want to reveal	1/0.2		Shopping	84/17.4
Age Group	Under 15	6/1.2		Social/Recreational	36/7.5
	15-25	270/55.9	Distance Travel	Up to 2 Km	33/6.8
	26-45	177/36.6		2-5 Km	97/20.1
	46-60	9/1.9		5-10 Km	185/38.3
	Above 60	21/4.3		10-20 Km	147/30.4
Education	Illiterate	9/1.9		More than 20 Km	21/4.3
	Up to 12th	227/47.0	Trip Frequency	1-2	186/38.5
	Graduate	235/48.7		3-4	223/46.2
	PG or Higher	12/2.5		5-7	74/15.3
Occupation	Student	157/32.5	Alternate Mode	None	6/1.2
	Unemployed	8/1.7		Auto Rickshaw	213/44.1
	Retired	21/4.3		Personal Vehicle	161/33.3
	Housewife	28/5.8		Taxi/Cab	103/21.3
	Supporting Staff	160/33.1	Alternate Mode Usage	Never/Long Ago	10/2.1
	Middle Level	101/20.9		Previous 15 days	345/71.4
	Higher Level	8/1.7		Previous 30 days	128/26.5
Income	Nil	158/32.3	Travel Frequency during COVID-19	At Home Totally	344/71.2
	10,000 or below	55/11.4		Decreased	42/8.7
	10,001 - 25,000	231/47.8		Increased	62/12.8
	25,001 - 50,000	33/6.8		Not Changed	35/7.2
	50,001 - 1 Lakh	5/1.0			
	1 - 2.5 Lakh	1/0.2			
Ownership	None	74/15.3			
	2-Wheeler	214/44.3			
	Car	34/7.0			
	Both	161/33.3			

Table 2 presents the access and egress information in terms of sample count and travel time (in minutes). Auto-rickshaw and personal vehicles constituted together around half of the access travel share before COVID-19. Notably, post COVID-19 cumulative share of taxi/cab had grown from around 10 to close to 20 percent. Overall, the mean travel time has increased by 45 percent (from 20 minutes to 29 minutes) in access travel and 35 percent (from 31 minutes to 42 minutes) in egress travel. This increase in access and egress travel time possibly can be linked to several reasons. It can be that the commuters had to choose the longer route length along road network due to restrictions in area-based movement, or non-availability of direct connectivity causing inter-system transfer, or unavailability of access/egress modes that the commuters used during pre-covid period (Khursheed and Kidwai 2022).

Table 3 Access-Egress Travel to Public Transport

Dimension		Before COVID-19		Post COVID-19	
		Sample/ Percent	Travel Time in Minutes -Mean (SD)	Sample/ Percent	Travel Time in Minutes -Mean (SD)
Access Mode	Walk	26/5.4	10.3 (8.1)	21/4.3	13.0 (12.7)
	Cycle Rickshaw	21/4.3	12.2 (9.3)	9/1.9	22.3 (14.0)
	Battery Rickshaw	90/18.6	24.8 (13.2)	45/9.3	27.2 (13.0)

	Bus	52/10.8	18.0 (10.0)	63/13.0	26.0 (9.74)
	Auto Rickshaw	125/25.9	20.6 (11.8)	108/22.4	31.6 (12.4)
	Taxi/Cab	40/8.3	18.5 (7.9)	100/20.7	34.7 (13.3)
	Personal Vehicle	129/26.7	22.9 (10.1)	137/28.4	29.8 (12.1)
	Overall	*483/100*	*20.6 (11.5)*	*483/100*	*29.6 (13.1)*
Egress Mode	Walk	20/4.1	10.5 (13.3)	27/5.6	11.8 (15.4)
	Cycle Rickshaw	16/3.3	14.5 (12.5)	5/1.0	21.0 (20.0)
	Battery Rickshaw	74/15.3	29.9 (13.3)	29/6.0	39.3 (16.9)
	Bus	76/15.7	43.7 (15.8)	72/14.9	55.3 (17.2)
	Auto Rickshaw	123/25.5	30.1 (17.3)	100/20.7	42.2 (16.4)
	Taxi/Cab	46/9.5	32.3 (16.7)	105/21.7	46.9 (17.7)
	Personal Vehicle	128/26.5	31.7 (14.0)	143/29.6	40.4 (15.5)
	Overall	*483/100*	*31.5 (16.8)*	*483/100*	*42.5 (18.9)*

4 PRELIMINARY INVESTIGATIONS

The sub-sections examine the change in satisfaction level with the transit service quality, access-egress pattern, and travel frequency post COVID-19 when the travel restrictions were eased.

4.1 Commuter's Satisfaction with Public Transport

Figure 2 shows the proportion of respondents and their perceived level of satisfaction with the overall service quality and the affected service quality attributes post COVID-19. From the figure, it can be observed that 54 percent of the respondents found no change in their overall satisfaction level with the PT services, while 43 percent reported an increase and 3 percent reported a decrease in their overall satisfaction level. He et al. (2023) from Hong Kong, China also observed similar findings that the PT passengers were mostly satisfied. Further, around 44% to 49% of the respondents reported an increase in satisfaction level from other service quality attributes. Moreover, 50% to 55% of the respondents perceived no change in quality attributes. On the contrary, a small fraction (0.4% to 3%) of the respondents reported a decrease in satisfaction level with the service quality attributes. The following is further observed:

- The service quality attributes with which the largest proportion of the respondents were satisfied are *seat availability (48.9%), overall ambience (46.6%), and service frequency (46.2%)*.
- The dissatisfaction with the service quality attributes was negligible. The attributes showing a bit higher dissatisfaction are *cleanliness – around stop/station (3.1%)*, *ticketing facilities (2.5%)*, and *boarding vehicle (2.1%)*.
- In general, around 50% of passengers perceived no change in their satisfaction level with all the attributes. However, numerically the service quality attributes with which the largest proportion of the respondents remained neutral are *cleanliness – inside vehicle (54.5%), crowd inside vehicle (54.2%),* and *ticketing facilities (53.8%)*.

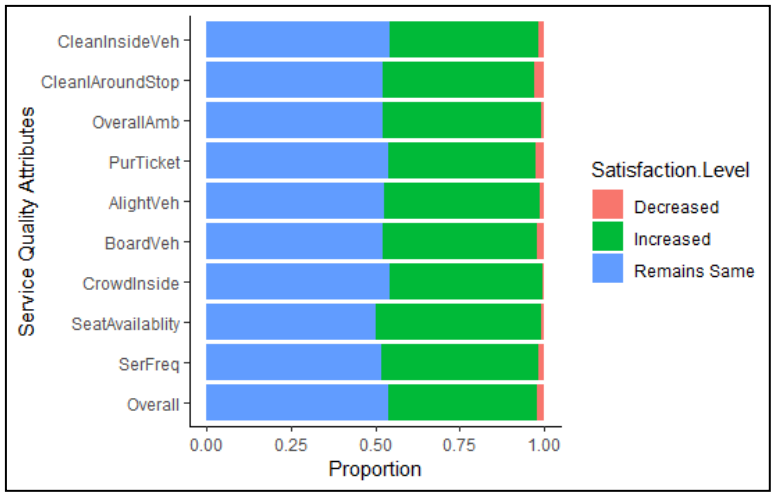

Figure 2 Respondents Perceiving Change in Satisfaction Level from Attributes

Overall, the mean change for service frequency is 17.9%, seat availability is 20.3%, crowd inside – vehicle is 19.8%, boarding vehicle is 18.6%, alighting vehicle is 19.7%, ticketing facilities is 18.2%, overall ambience is 19.8%, cleanliness around stop/station is 18.6%, cleanliness inside vehicle is 18.9%, and overall satisfaction is 19%. *It should be noted that the performance of each attribute had improved (~18 to 20%) with respect to the passengers' satisfaction level post COVID-19 period. Further, almost all attributes except two (cleanliness related) are linked with passenger comfort.* (Esmailpour et al. 2022) also showed higher preference of comfort dimension into explaining the service quality of Tehran bus transit during COVID-19.

4.2 Access-Egress Travel to Public Transport

Shifts in access-egress travel modes and changes in access-egress travel time due to COVID-19 are discussed in this section.

4.2.1 Shift in Access/Egress Travel Mode

Overall, 54 and 58 percent of respondents have changed their access and egress travel mode, respectively. **Figure 3** show the proportional change for various access and egress modes after the COVID-19 travel relaxations were implemented, respectively. Both figures indicate that the highest increase (2.5 times in access and 2.3 times in egress) is observed in Taxi/Cab usage as compared to other access-egress travel modes post COVID-19. It is because the large proportion of users (~40%) who were using auto rickshaw in pre-COVID-19 period, shifted to Taxi/Cab post COVID-19. Further, a one-up level change was observed in travel mode usage, e.g., cycle rickshaw users shifted to auto rickshaw and battery rickshaw access modes, while battery rickshaw users shifted to auto rickshaw and taxi/cab mode, and the auto rickshaw users shifted to taxi/cab mode. *This shift in access and egress modes clearly entails that the commuters from lower mobility (cycle rickshaw, battery rickshaw) had shifted to higher mobility-based transport modes (auto rickshaw), while auto-rickshaw users moved to taxi/cab transport concerning safety, and adherence to social restrictions.* The socioeconomic profile of these users reveals that despite the earnings of most of these users being 10-25K per month and working as supporting staff, they had chosen an expensive means of transport (taxi/cab).

However, in case of users who used bus as an access-egress transport mode, it was observed that close to 50 percent in access travel and 25 percent in egress travel shifted to either

auto-rickshaw, personal vehicle, or taxi/cab services. On the contrary, users who used to walk or used personal vehicles (95 to 99 percent) had not changed their egress travel mode, whereas 98 percent personal vehicle users continued using the same access travel mode. This could be attributed to the reason that the personal vehicle users remain in an enclosed space and hence they felt safe from the infection. This can be corroborated with the (Khursheed and Kidwai 2022) observations that New Delhi commuters felt private and active access-egress travel modes safest. Zafri et al. (2022) too had observed that the commuters in Bangladesh felt safe while using private travel modes. However, Abdullah et al. (2020) reported 7 percent increase in walking as a main mode during COVID-19 based on worldwide data. Furthermore, there was a negligible proportion of users who used cycle rickshaw as egress travel mode during pre COVID-19 period, but they shifted to walk during post COVID-19 period. Like personal vehicle users, walking alone felt safer.

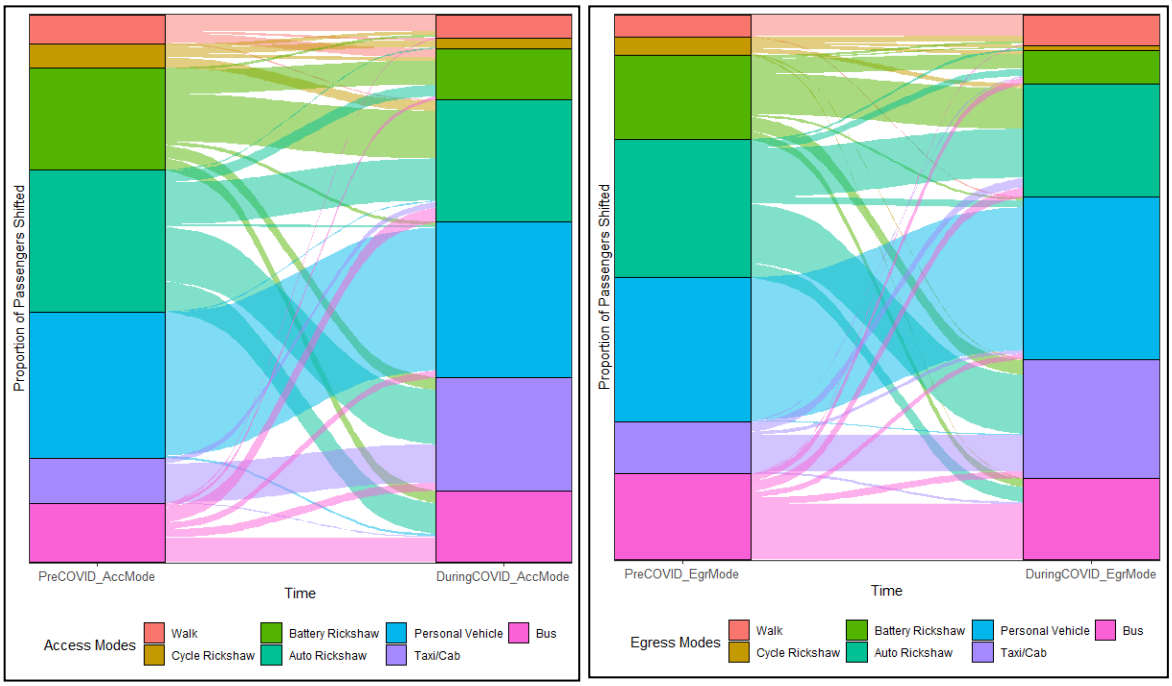

Figure 3 Shift in Users' Access and Egress Mode During post COVID-19

4.2.2 Effect on Access/Egress Travel Time

Figure 4 represents the number of respondents whose access and egress travel times have changed post COVID-19 period, respectively. Notably, around 88 percent of the respondents experienced an increase (green colour) in access and egress travel time as compared to pre-COVID period. This is for access-egress travel modes other than walk and cycle rickshaw. The increase in travel time was experienced by both, the ones who shifted to new travel modes as discussed before and the ones who did not change the access / egress travel mode (other than walk and cycle).

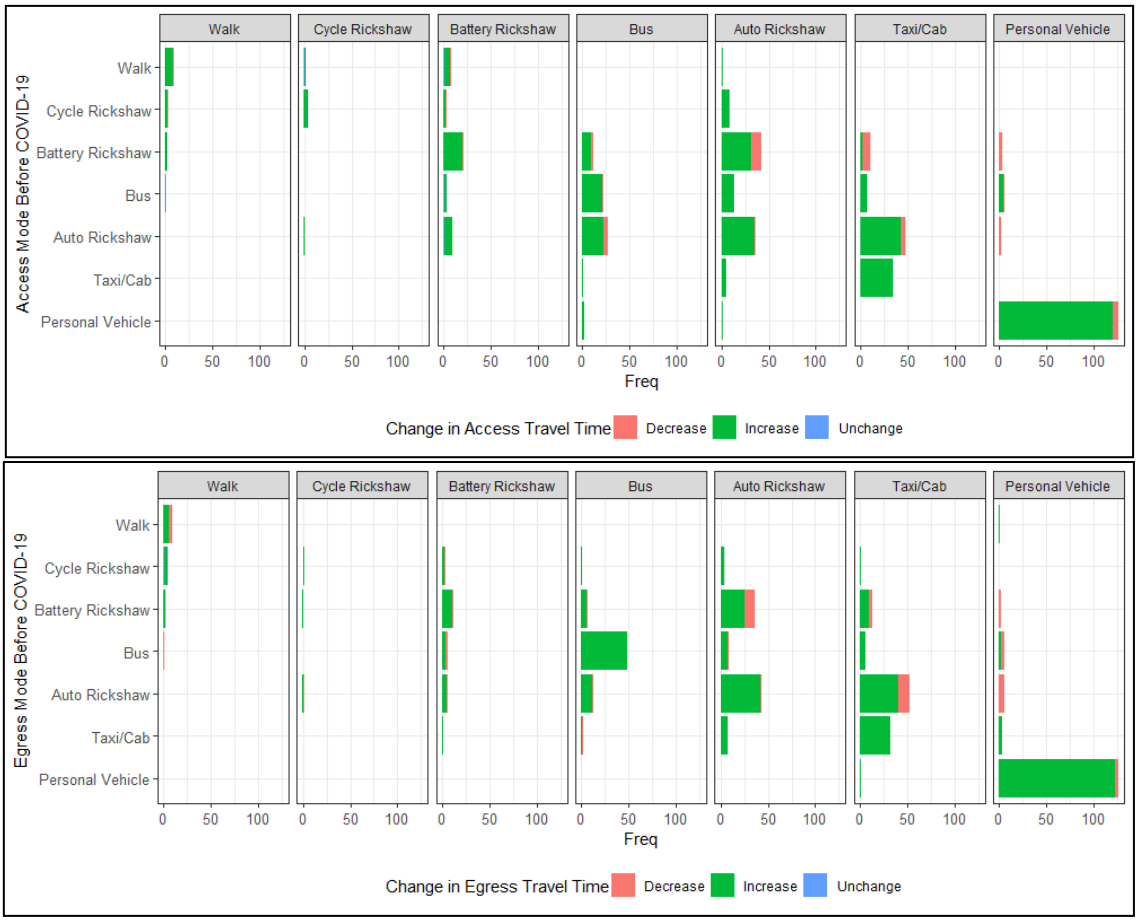

Figure 4 Egress Mode wise Respondents Counts whose Egress Travel Time Changed

The *mean difference* and *standard deviation in difference* of access and egress travel times (for both who changed access or egress travel modes as well as who did not change their modes) are estimated and presented in **Table 4** and **Table 5**, respectively**.** The mean difference of say 'walk against bus cell' in **Table 4** is obtained by deriving the mean of the differences in travel time (ΔT) of respondents whose access travel post COVID-19 was by bus mode that took time 't_d' and access travel pre COVID-19 was by walk mode that took travel time 't_b'. The difference in travel time post COVID-19 and pre COVID-19 is *'*$\Delta t' = (t_d - t_b)$. The mean and standard deviation of the *'*$\Delta t'$ is obtained thereafter as per statistical techniques. In the tables, the upper diagonal elements represent switch from lower mobility-based transport to higher mobility-based transport services, and vice-versa. It is interesting to note that even though some passengers had shifted from lower to higher mobility-based transport modes still they have experienced higher access and egress travel time post COVID-19. As mentioned before, the reason could be the possible detours in path, longer route length along road network, area-based movement restrictions, non-availability of direct connectivity (increase in transfer time), limited availability of access/egress travel services to commuters (increase in wait time), etc (Roychowdhury et al. 2020; Khursheed and Kidwai 2022).

Table 4 Mean Difference and SD in the Differences in Travel Time of Access Travel

	Post COVID–19						
A. Increase in Access Travel Time in minutes (Mean/SD)							
	Walk	Cycle	Battery	Bus	Auto	Taxi/Cab	Personal

			Rickshaw	Rickshaw		Rickshaw		Vehicle
Pre COVID–19	Walk	10.4/8.7	15.0/0.0	4.8/3.0	-	5.0/0.0	-	-
	Cycle Rickshaw	6.0/5.6	19.5/7.6	22.5/3.5	-	19.2/7.3	-	-
	Battery Rickshaw	9.5/12.0	-	12.7/5.9	12.4/12.4	14.1/10.8	27.5/3.5	-
	Bus	-	-	10.5/0.7	9.4/6.5	10.0/4.7	12.1/8.9	10.0/4.1
	Auto Rickshaw	-	25.0/0.0	14.5/8.0	9.0/4.8	14.5/8.2	17.5/10.7	-
	Taxi/Cab	-	-	-	9.0/0.0	11.6/5.9	14.7/8.7	-
	Personal Vehicle	-	-	-	9.5/3.5	15.0/0.0	-	8.0/5.6
B. Decrease in Access Travel Time in minutes (Mean/SD)								
Pre COVID–19	Walk	-1.0/0.0	-	-1.0/0.0	-	-	-	-
	Cycle Rickshaw	-1.0/0.0	-	-1.0/0.0	-	-	-	-
	Battery Rickshaw	-	-	-19.0/0.0	-9.0/1.4	-16.0/5.2	-11.4/7.2	-17.0/12.1
	Bus	-	-	-	-1.0/0.0	-	-	-22.0/12.7
	Auto Rickshaw	-	-	-	-13.8/5.2	-1.0/0.0	-13.0/7.6	-10.0/0.0
	Taxi/Cab	-	-	-	-	-	-	-
	Personal Vehicle	-	-	-	-	-	-	-8.5/7.8

Table 5 Mean Difference and SE in the Differences in Travel Time of Egress Travel

		Post COVID–19						
A. Increase in Egress Travel Time in minutes (Mean/SD)								
		Walk	Cycle Rickshaw	Battery Rickshaw	Bus	Auto Rickshaw	Taxi/Cab	Personal Vehicle
Pre COVID–19	Walk	12.3/9.1	-	-	-	-	-	2.0/0.0
	Cycle Rickshaw	2.7/2.8	16.0/19.8	19.5/7.8	10.0/0.0	27.5/9.5	11.0/0.0	-
	Battery Rickshaw	1.0/0.0	20.0/0.0	13.8/7.1	14.8/6.3	24.7/14.8	22.4/10.3	-
	Bus	-	-	10.2/7.7	12.8/4.9	12.5/3.8	6.5/1.9	15.0/0.0
	Auto Rickshaw	-	1.0/0.0	29.0/13.4	11.2/3.3	18.5/7.6	19.2/10.9	-
	Taxi/Cab	-	-	25.0/0.0	15.0/0.0	12.7/10.6	15.5/7.2	12.0/6.1
	Personal Vehicle	-	-	-	-	-	15.0/0.0	9.8/6.6
B. Decrease in Egress Travel Time in minutes (Mean/SD)								
Pre COVID–19	Walk	-1.0/0.0	-	-	-	-	-	-
	Cycle Rickshaw	-1.0/0.0	-	-4.0/0.0	-	-	-	-
	Battery Rickshaw	-	-	-22.0/0.0	-12.0/5.6	-9.5/3.8	-12.0/2.6	-13.0/2.8
	Bus	-1.0/0.0	-	-6.0/1.4	-	-15.0/0.0	-	-16.7/5.7
	Auto Rickshaw	-	-1.0/0.0	-22.0/0.0	-8.0/0.0	-1.0/0.0	-14.3/5.4	-12.7/5.9
	Taxi/Cab	-	-	-	-15.0/0.0	-20.0/0.0	-	-
	Personal Vehicle	-	-	-	-	-	-	-11.0/9.5

4.3 Primary Trip Frequency

Table 6 represents the percentage of respondents whose travel frequency was affected during the COVID-19, with respect to their travel information and occupation. 25 percent of respondents who travelled 3-7 times (unidirectional) per week had either unchanged or increased travel frequency. 90 percent of commuters travelling for short distances of up to 2 kilometers remained at home during COVID-19 travel restrictions. Contrarily, the travel frequency of around 40 percent of passengers travelling over 20 kilometers has increased or remained unchanged. Of all professions, around 90 percent of the students, and 77 percent of the supporting staff stayed at home completely during the COVID-19 restrictions period. 37 percent of shopping-related trips either remained unchanged or had increased. Further, around 37 percent of unemployed and middle-level professionals, 50 percent of housewives, and close to 63 percent of higher-level professionals reported either an increase or no change in their travel frequency.

Further, **Figure 5** presents a categorical representation specific to the increase and unchanged travel frequency among respondents co-relating with their occupation, trip purpose, and total trip length. The figure illustrates that increase and no change in travel frequency are for passengers whose occupation and trip purposes were not impacted by COVID-19. These were primarily: work-related trips for the employed professionals, shopping for housewives, social/leisure trips for retired individuals, and education-related trips for students. Further, travel frequency during COVID-19 travel restricted period has remained unchanged or increased for commuters who earn little or nothing and mostly travelled between 5 to 10 kilometres, and for higher earnings and retired commuters who travelled for more than 10 kilometres trip length. Abdullah et al. (2020) also observed that shopping/leisure trips and longer trips were prominent during the COVID-19 as per the worldwide data.

Table 6 Travel Information and Change in Travel due to COVID-19

	At Home Totally (N=344)	**Decreased (N=42)**	**Increased (N=62)**	**Not Changed (N=35)**
Trip Frequency				
1-2	149/80.1	15/8.1	11/5.9	11/5.9
3-4	150/67.3	17/7.6	40/17.9	16/7.2
5-7	45/60.8	10/13.5	11/14.9	8/10.8
Trip Purpose				
Work	144/69.2	15/7.2	32/15.4	17/8.2
Education	140/90.3	4/2.6	7/4.5	4/2.6
Shopping	39/46.4	14/16.7	19/22.6	12/14.3
Social/Recreational	21/58.3	9/25.0	4/11.1	2/5.6
Total Distance Travel				
Up to 2 Km	30/90.9	2/6.1	-	1/3.0
2-5 Km	68/70.1	9/9.3	13/13.4	7/7.2
5-10 Km	118/63.8	19/10.3	33/17.8	15/8.1
10-20 Km	115/78.2	12/8.2	13/8.8	7/4.8
More than 20 Km	13/61.9	-	3/14.3	5/23.8
Occupation				
Student	140/89.2	3/1.9	8/5.1	6/3.8
Unemployed	4/50.0	1/12.5	1/12.5	2/25.0
Retired	14/66.7	2/9.5	3/14.3	2/9.5
Housewife	10/35.7	4/14.3	7/25.0	7/25.0
Supporting Staff	124/77.5	17/10.6	15/9.4	4/2.5
Middle Level	51/50.5	13/12.9	26/25.7	11/10.9
Higher Level	1/12.5	2/25.0	2/25.0	3/37.5

Figure 5 Change in Respondents' Trip Frequency during COVID-19

5 SATISFACTION CHANGE MODEL

Multiple linear regression model is applied to analyze change in overall satisfaction with the service quality attributes. Assumptions regarding regression modelling are examined before creating the model (Roback and Legler 2021). These are discussed herein.

Correlations within independent variables and with dependent variables are observed to be around 0.3 to 0.4 which is acceptable for consideration in regression modelling (Hair et al. 2019). Variance Inflation Factors (VIF) for all the variables are found to be lower than 5 which indicates that all variables are free form collinearity issue. Mutual information scores are estimated and are found moderately correlated; and there exist no serious multicollinearity among independent variables. Crowd Inside, Seat Availability and Service Frequency are found to have least mutual information score among all independent variables. These initial tests indicate that the data attributes can be analysed through regression modelling. At first, all variables are used as regressor wherein it was observed that the crowd inside, seat availability, and service frequency variables were statistically insignificant. Thus, utilising backward section method, these variables were removed one after another and simultaneously model performance check were done. Therefore, six independent variables with Overall satisfaction as dependent variables were used to form a regression model. The summary of the fitted model is shown in **Table 7**. All the six variables were statistically significant. The regressed model has R^2 0.29 which is good in social and behavioural research problems (Ozili 2022). Further, elasticity analysis of satisfaction is carried out using the **Equation 1**.

$SE = (\Delta O/\Delta A_i) * (A_i /O)$ **Equation (1)**

Table 8 shows the elasticity of quality attributes which indicates that alighting from vehicle and cleanliness at and around stop/station are the most and least sensitive sub-attributes, respectively.

Table 7. Results of Multivariate Linear Regression Model

Variable	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	4.029	1.438	2.801	0.005 **

Alighting Vehicle	0.162	0.048	3.361	0.0008 ***
Boarding Vehicle	0.123	0.046	2.646	0.008 **
Purchasing Ticket	0.133	0.046	2.845	0.004 **
Overall Ambience	0.112	0.045	2.456	0.014 *
Cleanliness – At & Around Stop/Station	0.118	0.043	2.699	0.007 **
Cleanliness – In-Vehicle	0.140	0.046	3.020	0.002 **
Significance codes: '***' 0.001 '**' 0.01 '*' 0.05 Residual standard error: 20.54 on 476 degrees of freedom Multiple R-squared: 0.29, Adjusted R-squared: 0.28 F-statistic: 32.82 on 6 and 476 DF, p-value: $< 2.2 \times 10^{-16}$				

Table 8. Satisfaction elasticity of Quality Attributes

Attribute	**($\Delta O/\Delta A_i$)**	**(A_i /O)**	**SE (Rank)**
Alighting Vehicle	0.162	1.032	0.156 (1)
Boarding Vehicle	0.123	0.968	0.119 (4)
Purchasing Ticket	0.133	0.953	0.126 (3)
Overall Ambience	0.112	1.035	0.115 (5)
Cleanliness – At & Around Stop/Station	0.118	0.992	0.117 (6)
Cleanliness – In-Vehicle	0.140	0.997	0.139 (2)

6 POLICY IMPLICATIONS

Considering the travel and socioeconomic characteristics of respondents and transit profile, several policies are recommended to improve transit service for passengers within budget realizing the shock to combat pandemic situation. (Gkiotsalitis and Cats 2021) suggested several strategical and tactical planning measures to provide safe and satisfactory service to the passengers. Stop-skipping, time-table scheduling utilizing transfer synchronization to reduce transfer time, crowd-management by delivering real-time crowd information, regulating passengers at entrance by tokenizing facility, and putting limitations on over boarding are few of the suggested measures. (Negm and El-Geneidy 2024) suggested that targeting low-income zones of land for implementing accessibility-based planning measures may lead to greater returns in post COVID-19 era. Based on the present study, the following can be considered for implementation:

a. The passengers were mostly travelling for longer trip lengths (5-20 kilometers) and hence transfer synchronization while travel-time scheduling can reduce the passengers waiting time at stops and hence may be found an appropriate policy measure to reduce crowd at station. Regarding crowd management inside the vehicles, it can be dealt by stop-skipping approach to avoid over boarding and crowded stops, delivering real-time crowd information at stop/stations to the passengers, and regulating passengers' entry by tokenizing wait system facility.
b. Fare revision shall not be exercised as most of the passengers are earnings in between 10-25K per month and are supporting staff or/and at middle level job positions. Thus, any hike in fare will burden their daily living. In fact, many of the lower job position holders lost their job during the COVID-19.
c. Cleanliness around stops/stations had been observed to receive the highest decrease in satisfaction. However, it was found least sensitive in contributing towards overall service quality during the pandemic. On the contrary, cleanliness – inside the vehicle is the second most sensitive attribute that contributed to the overall satisfaction level of the passengers. Nevertheless, both aspects of cleanliness are mandatory and irrespective

of the satisfaction ratings the periodic cleanliness at and around stop/station and inside vehicles shall be practiced for further improving satisfaction among passengers.

d. The ticketing facility is found to be a sensitive aspect in overall passenger satisfaction as well as one of the most neutral attributes among the respondents. Two kinds of ticketing services, both e-ticketing purchasable over smartphone and smart card or coupon-based facilities can be exercised in this case since the commuters are mostly of two groups, one is graduate or more and have middle-level job profession, second is supporting staffs and 12th or lower educated. The latter group can make use of coupons or seamless smart cards whereas the first group can take advantage of the technology. Both facilities will benefit in creating physical separation among passengers' groups as well as help in managing the crowd at the ticketing service center thus preventing covid infection.
e. Travel restrictions have least or no effects on trips related to shopping for housewives and social/leisure for retired persons. Pointedly, grocery shopping and delivery through e-commerce platforms are already in a strong place in the study region. Thus, it may be conditional that these trips are hedonically motivated trips.
f. Concerning access and egress mode selection during post COVID-19, the concerns of passengers were fear of infecting themselves while accessing main travel mode. This is understandable through observations in shift from lower mobility-based to higher mobility-based modes and bus users to private transport service despite high travel expenses (to ensure infection free personal space); and walk and personal vehicle users adhering to the same mode as they perceived independent travel safest from infection. The provision of transparent shields demarketing the passenger sphere is a possible solution for providing personal protection to the passengers in access and egress travel modes.
g. Alighting is found to be a sensitive attribute in passengers' satisfaction. It must be noted that the low floor fleet is in service under conventional bus transit and metro rapid transit has platform alighting service. Thus, there is no question of system infrastructural improvisation here.
h. Further, concerning passengers' satisfaction from transit service quality indicates that the satisfaction has improved overall and at individual attribute level too. This means that the quality attributes have improved in the post pandemic period. Nevertheless, the mean satisfaction level of service frequency aspect was lowest. That suggests that the respondents' satisfaction has not improved as the service was operating with low frequency. Temporary time-table rationalization for rush hours can be an exercise.

However, to further improve the services during the pandemic in future these policy interventions shall be exercised which will enable the transit facility to deliver a more attractive and satisfactory transit service to the commuters.

7 CONCLUSIONS

The study presents a unique contribution to pre and post COVID-19 comparative assessment studies by examining transit commuters' access-egress behavior, their primary trip frequency, and perceived satisfaction levels with the transit facilities. The novelty lies in its focused analysis of these key aspects, shedding light on the evolving dynamics in the wake of the COVID-19 pandemic. In those aspects, the study investigated the impact of COVID-19 on PT passengers' travel behavior and satisfaction in New Delhi, India. The CAPI survey was conducted at identified bus terminals and metro interchange stations. Preliminary analysis of responses collected from PT passengers are done regarding their change in primary trip

frequency, access and egress travel behavior, and commuters' satisfaction with public transport. Further, a multiple linear regression analysis was done to model the effects of service quality attributes on overall satisfaction. The main findings are:

- Passengers shifted from lower to higher mobility modes and from public to private modes for access-egress travel, and their access and egress travel times increased during the pandemic.
- Passengers' satisfaction level improved overall and for most of the service quality attributes during the pandemic, wherein service frequency was found to be relatively lowest.
- The most influential attributes on overall satisfaction were identified as alighting from vehicle, boarding a vehicle, purchasing ticket, cleanliness in-vehicle, and cleanliness at stop/station.

The article suggests some policy implications to improve PT service and attract passengers in the post-pandemic period. These include providing transparent shields demarcating the passenger sphere in access and egress modes, maintaining cleanliness at stops/stations and inside vehicles, providing seamless travel and e-ticketing facilities, and improving service frequency while managing crowd at stop/stations and inside the vehicle. However, the study had only limited the transit performance assessment only from operational, functional, and infrastructural aspects. Financial and governmental regulations-based performance are also involved during the pandemic period. However, these two falls outside the study's scope and hence not looked upon. Further, the study provides valuable insights for transit systems preparing for similar pandemics in the future. These insights will help transit service providers and policy makers to provide access-egress travel services from passengers' origin to the stop/stations and implement measures to make the services attractive and satisfactory for lower as well higher socio-economic passengers. However, it fails to provide critical assessment on magnitude of trip replaced post COVID-19 due to online shopping, e-learning, etc.; and specific reason for increase in access-egress travel time. The study also highlights the need for further research to understand the long-term effects of COVID-19 on urban mobility behavior.

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