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# POST COVID-19 ACCESS-EGRESS ATTRIBUTES FOR URBAN METRO TRANSIT USERS IN DELHI

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**KEY WORDS:** Access-Egress Mode Choice, Motorized-Nonmotorized Modes, Main Haul Time & Distance, Multinomial Logistic Regression, Urban Metro Transit System, Delhi Metro.

**ABSTRACT:**

The BLUE line of Delhi Metro (DM) has been examined to identify the post COVID-19 access–egress attributes of users. An on-board survey of metro commuters is conducted in February and March 2021. The respondents reported six different modes for access and egress trips to nearest metro stations with 38.7% and 43% users opting for walking for access-egress trip respectively. The E-rickshaw is observed to be most preferred para-transit mode whereas private vehicle has small mode share for access-egress trip. It is revealed that 46.5% of respondents are captive riders whereas 51% owns at least one motorized private vehicle. The average access and egress distance covered by walking is (0.81± 0.32/0.35) Km respectively. The average access and egress trip time by walking is (11.19±3.73) and (11.07±4.45) minutes respectively. The average access and egress trip time by E-rickshaw is (13.21±4.09) and (12.56±2.95) minutes respectively. The access and egress trip time by motorized modes are in the range of (12.36-14.39) and (10.41-13.56) minutes respectively. The average main haul distance across all access-egress modes is observed to be (19.69±11.19) Km. To understand the factors influencing the access–egress mode choice multinomial logistic (MNL) regression models are proposed. The access-egress time and distance are observed to be significant factors in access-egress mode choice. Less parking facility offered by DM is significant factor in access mode choice. Occasional commuters are only significant factor in context with frequency of travelling in DM.

## 1. INTRODUCTION

Delhi has been long witnessing a perpetual shrinking of mode share of public transportation (PT). During the period 1994-2008, the PT share over 50% in 1994, drops to 42% in 2002 (Tiwari, 2003) which further drops to 29% in 2008 (RITES, 2010). It further declined to 20.7% in 2017-2018 (ESD, 2019). Delhi with a population of 18.7 million in 2018 (ESD, 2019) is among one of the high population density cities in the world (Mohan, 2013). Among all the big metropolitan cities in India, Delhi has highest motor-vehicles ownership (Tiwari, 2013). It is reported, that app. 0.15 million private vehicles including two and four wheelers are added on already congested roads of Delhi during 2018-2019 (DES, 2019). Due to socio-economic and demographic changes, the travel demand is increasing but PT share is not keeping pace with it due to surge in the share of private vehicles. The Delhi Metro (DM) is a popular PT mode with substantial share. The mode share of DM also witnesses a significant drop due to travel restrictions imposed during COVID-19 pandemic. The services of DM terminated in March 2020 which resumed in a restricted manner on September 09th, 2020 with new travel protocols.

The “Blue Line” is busiest corridor of DM. The line commissioned in December 2005 is the longest origin-destination line of DM between Dwarka-Sector 21 and NOIDA City Centre.

With the recent expansion of Blue line in March 2019 connecting NOIDA city centre to NOIDA electronics city, the total route of “Blue line” stood at 65.35 kilometres which is served by 56 stations including 51 elevated, 5 underground and 1 at grade.

The ridership of metro is a function of the access and egress time spent by users (Murray et al., 1998). The attributes of access and egress (feeder) modes also affect the ridership. The feeder components are important and enervated parts of main PT trip, due to the time and cost factors involved. As a result, with a rise in access and egress time, the ridership of PT system starts decreasing (Cervero, 2001). The factors influencing access and egress mode choice include socio-economic condition, population density and ownership of vehicle among other factors (Goel & Tiwari, 2016; Krygsman et al., 2004). Based on these factors, this research is directed to understand the impact of travel restriction imposed due to COVID-19 pandemic on access-egress components of a metro trip in Delhi and influence of other factors on feeder mode choice.

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## 2. LITERATURE REVIEW

The ridership of metro users is dependent on the comfort qualities of access modes (Givoni et al., 2009; Givoni & Rietveld, 2007) and on the time & cost spent by the users on the access and egress modes (Murray, 2001).

Access and egress trips are the feeble components of metro and as a result with a surge in access and egress time, the serviceability of PT system decreases (Cervero, 2001). An efficient PT system is dependent on the extent of synchronization of the access-egress routes, catchment area, operational capacity, speed and urban form characteristics (Mishra et al., 2012). The access and egress parameters determine the usage of metro in a given area. A higher than acceptable access and egress time and distance are deterrent to an affordable and attractive PT as an alternative to unimodal private vehicle (Krygsman et al., 2004).

The factors studied by other researchers includes age, trip purpose, catchment area, main haul length/time, population density, access-egress time, socio-economic conditions and few other parameters (Goel & Tiwari, 2016; Krygsman et al., 2004; Tan et al., 2020). It is concluded that access-egress characteristics varies significantly across different socio-economic and demographic conditions (Ribeiro et al., 2021). It has been reported in several researches across different parts of world that access and egress time of walking mode to PT considering local socio-economic and demographic conditions varies as 5.9-6.2 minutes (Krygsman et al., 2004) and 7.6-7.9 min (Yu & Lin, 2014) respectively.

It has been noted that average access-egress walking distance to metro considering local socio-economic and demographic conditions varies from 447 meter to 1291 meter (Soest et al., 2020). Parking facility at metro station is another factor influencing access-egress mode which has been revealed that an increase in parking fare at park and ride stations is more likely to attract park-and-ride users towards the transit all-way option when compared with the private vehicle all-way option (Habib et al., 2013). These studies are conducted in pre COVID-19 era in different parts of world with different socio-economic and demographic conditions. Few macro level researches in pre COVID-19 era have been conducted to identify the access-egress behaviour of DM users. The micro level study on access-egress attributes for DM users have not been conducted post COVID-19 and as such has further potential scope of research.

Therefore, considering the above-mentioned scope of the research, this micro level study considering socio-economic and demographic conditions of catchment area of BLUE line corridor is aimed to identify the impact of travel restrictions due to COVID-19 pandemic on access-egress attributes of DM users. The access-egress time and distance, vehicle ownership, parking facility provided by DM and travel frequency of DM users are considered in the spatial-temporal analysis to identify the influence on access-egress mode choice post COVID-19.

## 3. ACCESS-EGRESS MODES FOR METRO

There are various access-egress modes feeding the DM which consist of walking, para-transit, transit modes and personal vehicles. Walking is one of the common and convenient access-egress modes involving physical effort only. Walking falls under non-motorized mode category. As shown in figure 1, several types of para-transit and transit modes operate in Delhi, which are very crucial for the daily travel mobility. The para-transit refers to those travel modes which have flexible schedule and are responsive to individual origin-destination location.

Most of the para-transit modes operating in Delhi are privately operated, which includes both motorized (E-rickshaw, Auto-rickshaw) and non-motorized (cycle-rickshaw). The E-rickshaw and Auto-rickshaw are having a capacity to ferry 4 and 3 passengers respectively. The transit motorized modes consist of DTC buses and feeder buses.

The DTC is run by Delhi government and has a developed network but also has its own limitations related to synchronized frequency and spatial coverage in respect of DM routes. Presently, the feeder buses managed by DM are operating on very few routes with respect to catchment area. In post COVID-19 travel protocols, the authorities have reduced the plying capacities of E-rickshaw, Auto-rickshaw, private vehicle to 2, 1, 2 passengers respectively and DTC/Feeder buses to half of sitting capacity.

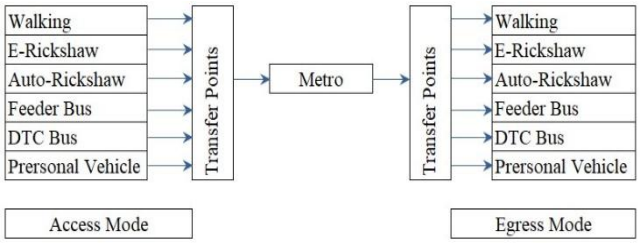



Figure 1. Schematic Outline of Multimodal Transport System (Delhi Metro as PT Mode)

## 4. RESEARCH METHODOLOGY

In the present research, to investigate access-egress attributes of DM users, a sizeable and detailed commuter travel data is required. A physical on-board survey through a comprehensive and suitable survey proforma is conducted post COVID-19 period on week days in February and March 2021. The survey proforma is designed to extract the following information.

1. Personal Information of the passenger: Gender, age, vehicles ownership.
2. Travel Information of the passenger: Origin-destination, convenient/preferred access egress mode along with distance & time spend, users' preference of parking facilities offered by DM, frequency of travelling besides several other questions pertaining to different attributes of access-egress trip.

A total of 742 random passengers boarded at 34 stations of BLUE line are interviewed and based on data cleaning, the data of 630 passengers comprising of 266 female and 364 male respondents is used for spatial analysis. In this survey, the completion rate observed is 84.9%. The data based on the questionnaire is collected and tabulated in statistically standard format and scrutinized logically. The spatial and temporal analysis of survey data is performed using various statistical methods including descriptive statistics and cross tabulation. Subsequently, multinomial logistic (MNL) regression is performed to understand the inter-relationship among various factors related to access-egress attributes of DM users post COVID-19. The results of the spatial-temporal analysis are presented in the subsequent sections.

## 5. MODE SHARE ANALYSIS

During the data collection, the respondents are asked about their mode choice of access-egress trip. They are asked to state the most commonly used access-egress mode based on availability and convenience post COVID-19 period. Their responses are presented in table 1.

| S. No. | Modes Used | Blue Line | |
|---|---|---|---|
| | | Access trips Number (%) | Egress trips Number (%) |
| 1 | Walking | 244 (38.7) | 271 (43) |
| 2 | E-rickshaw | 226 (35.9) | 212 (33.6) |
| 3 | Auto-Rickshaw | 97 (15.4) | 100 (15.9) |
| 4 | Feeder Buses | 16 (2.5) | 9 (1.4) |
| 5 | DTC buses | 10 (1.6) | 16 (2.5) |
| 6 | Personal Vehicles | 37 (5.9) | 22 (3.5) |
| | Total | 630 (100) | 630 (100) |

Table 1. Access-Egress mode share

Table 1 shows that walking has significant mode share of 38.7% and 43% of access-egress trip respectively. It shows that flexibility and zero cost involved with walking may be the reason to be the most preferred mode. Moreover, health and precaution against COVID-19 infection may be other factors for this choice. However, this share may vary depending on few other factors including age, gender, weather conditions, distance and ease of walking.

The next preferred mode is E-rickshaw with a share of 35.9% and 33.6% of access-egress trip respectively. It shows that easy accessibility, availability and flexibility in the route is the reason for its use in smaller access-egress distance. According to a study (Goel & Tiwari, 2016) the average combined access-egress share of Bicycle and Cycle-rickshaw is 10.5%. In the present study, the average access-egress mode share of E-rickshaw is reported to be 34.75%. It is observed that E-rickshaw has replaced Cycle-rickshaw to a larger extent in Delhi. It is further noted that Auto-rickshaw has higher share with respect to feeder bus, DTC bus and private vehicle. It has a mode share of 15.4% & 15.9% in access-egress trip respectively.

According to a study (Goel & Tiwari, 2016) the average access-egress share of Auto-rickshaw is 21.5% which in the present study has drop down to little over 15%. This shift may be attributed to change in mode share preference post COVID-19 due to safety measure. The total share of motorized paratransit (E-rickshaw & Auto-rickshaw) mode is 51.3% and 49.5% of access-egress trip respectively.

It is observed that, the feeder and DTC bus have practically insignificant share towards access-egress mode highlighting the inefficiency and non-coordination of such modes in reference to DM. The combined motorized transit (DTC and Feeder bus) share is only 4.1% and 3.9% in access-egress trip respectively. The private vehicle mode share constitutes only 5.9% and 3.5% for access-egress trip respectively. It is to be noted that though most of the metro stations have parking facilities, a small proportion of choice riders prefer to use private vehicle as access-egress mode. The results so obtained for choice riders could be attributed to several variables including age, gender, travel time, travel cost among other factors (Arasan et al., 1998). The above results show asymmetric mode share distribution for both access-egress trip with major share of walking. The spatial analysis shows that walking and E-rickshaw modes dominate the access-egress trip. One possible reason for such attribute is that all other modes have enclosed space which in COVID-19 pandemic has been advised by health professionals to avoid stopping the spread of COVID-19 infection.

Table 2 shows the vehicle ownership share of the respondents. It shows that 46.5% a significant proportion do not own any vehicles and are captive riders. A very small share 2.5% of users possess bicycle. The choice riders having private vehicles (two and/or four wheelers) are observed to be 51%. The choice riders include 28.8% of those who own two-wheeler and 19% are those who own four- wheeler.

| S. No. | Vehicles Category | Number (%) |
|---|---|---|
| 1 | No Vehicles | 293 (46.5) |
| 2 | Bicycle | 16 (2.5) |
| 3 | Two-Wheeler | 181 (28.8) |
| 4 | Four-Wheeler | 120 (19) |
| 5 | Two & Four-Wheeler | 20 (3.2) |
| | Total | 630 (100) |

Table 2. Vehicles ownership

The spatial analysis of the data suggests that DM is a preferred mode for captive riders whereas the choice riders may prefer their vehicles for the same trip. This behaviour could be attributed to the non-coordinated and non-synchronized transportation planning and management among different feeder modes. It is one of the possible reasons for the traffic congestion on Delhi roads. The variation in the fare of different access-egress modes is also a factor for commuters to opt for walking or E-rickshaw among other factors.

## 6. TRAVEL TIME AND DISTANCE OF ACCESS-EGRESS MODES

In the survey, the DM users are also enquired about their access-egress distance and time from nearest origin and destination metro stations respectively.

Table 3 shows the average distance and time along with the standard deviation of different access-egress modes. The average access and egress distance covered by walking is ($0.81\pm0.32/0.35$) Km respectively.

It is observed that depending on demographic and socio-economic factors the average access/egress walking distance to metro varies from 447 meter to 1291 meter (Soest et al., 2020). The average access and egress trip time taken by walking is ($11.19\pm3.73$) minutes and ($11.07\pm4.45$) minutes respectively which is higher comparing other observed time of 5.9 minutes (Krygsman et al., 2004) and 7.6-7.9 minutes (Yu & Lin, 2014).

| Serial Number | Mode Choice | Access Time (min.) | Access Distance Km.) | Egress Time (min.) | Egress Distance (Km.) | Main Haul Time per trip (min.) | Main Haul Distance per trip (Km.) | (Access+Egress) time/Main Haul Time | (Access+Egress) distance/Main Haul Distance |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Walking | 11.19±3.73 | 0.81 ±0.32 | 11.07 ±4.45 | 0.81 ±0.35 | 40.03 ±21.33 | 18.81 ±11.74 | 0.556 | 0.086 |
| 2 | E-Rickshaw | 13.21±4.09 | 2.02 ±0.69 | 12.56 ±2.95 | 1.87 ±0.49 | 42.16 ±18.62 | 19.94 ±10.64 | 0.611 | 0.195 |
| 3 | Auto-Rickshaw | 12.36±2.66 | 2.85 ±0.66 | 12.18 ±2.88 | 2.66 ±0.74 | 46.01 ±21.27 | 22.11 ±11.96 | 0.533 | 0.249 |
| 4 | Feeder Buses | 14.13±2.63 | 3.29 ±0.75 | 13.56 ±3.51 | 3.04 ±0.69 | 39.69 ±14.19 | 18.75 ±6.67 | 0.697 | 0.337 |
| 5 | DTC buses | 14.39±4.19 | 3.82 ±0.96 | 13.25 ±3.34 | 3.23 ±0.94 | 32.14 ±12.84 | 13.08 ±6.23 | 0.859 | 0.538 |
| 6 | Personal Vehicles | 12.76±4.86 | 3.61 ±1.02 | 10.41 ±3.33 | 2.45 ±0.79 | 41.05 ±11.52 | 19.65 ±9.91 | 0.564 | 0.308 |
| | TOTAL | 12.32±3.89 | 1.84 ±1.12 | 12.09 ±3.72 | 1.61 ±0.93 | 41.64 ±20.04 | 19.69 ±11.19 | 0.586 | 0.175 |

Table 3. Access-Egress time and distance per trip

The E-rickshaw has average access and egress distance of (2.02±0.69) Km. and (1.87±0.49) Km. respectively. The average access and egress trip time of E-rickshaw is (13.21±4.09) minutes and (12.56±2.95) minutes respectively. The access and egress distance of other motorized modes are in the range of 2.85-3.82 Km. and 2.45-3.23 Km. respectively. The access and egress trip time of motorized modes are in the range of 12.36-14.39 minutes and 10.41-13.56 minutes respectively. The results show that E-rickshaw travels the least distance among all motorized modes for access-egress trip. In conclusion, the DM users travel on an average access-egress distance of 3.45 Km. and spend 24.41 minutes per trip.

These higher out of metro travel time and distance reduces the efficiency of the DM especially for short main haul distances (MHD) due to more time spent in feeder mode. It is to be noted that the reported access-egress time includes actual travel plus waiting time of different modes excluding walking mode.

It can be inferred that due to variation in waiting time of different modes, the respective access-egress time is not a linear function of access-egress distance. It is revealed that across all mode choice the average main haul time (MHT) per trip varies between (32.14±12.84) to (46.01±21.27) minutes with riders using DTC bus having least and Auto-Rickshaw riders having highest MHT. The average MHT across all access-egress modes is observed to be (41.64±20.04) minutes.

It is noted that ratio of average (access + egress) trip time to average MHT varies between 53.3% and 85.9% whereas Auto-rickshaw and DTC bus has the lowest and highest ratio respectively. The above ratio is observed to be 58.6% across all the modes for present study. The result suggests that across all modes the (access + egress) time is 58.6% of the MHT which is substantially high. It is further noted that ratio of average (access + egress) trip distance to average MHD varies between 0.086 and 0.538 whereas walking and DTC bus has the lowest and highest ratio respectively.

The above ratio is observed to be 0.175 across all the modes for present research. The result suggests that the average (access + egress) distance is 17.5% of the MHD which is high. It is noted that average MHT and MHD are non-linear function of average (access + egress) time and distance respectively. It is also observed that across all mode choice the average MHD per trip varies from (13.08±6.23) to (22.11±11.96) Km. with DM riders using DTC bus having least and DM riders using Auto-Rickshaw having the highest MHD. The average MHD across all access-egress modes is observed to be (19.69±11.19) Km. According to a study (Goel & Tiwari, 2016) the average MHD observed is (20.3±0.5) Km.

## 7. FREQUENCY DISTRIBUTION OF ACCESS-EGRESS TIME AND DISTANCE OF DIFFERENT MODES

A temporal analysis is conducted on the access-egress trip considering the relative mode shares of motorized and non-motorized modes and the results are presented in figure 2. This figure shows the frequency distribution of the access-egress time in respect of the motorized and walking modes.

It is observed that the average access time is 11.19 minutes and 13.02 minutes for walking and motorized modes respectively. The average egress time is 11.71 minutes and 13.02 minutes for walking and motorized modes respectively. It is noted that for both access-egress trip walking takes less time than motorized modes. It is inferred that access-egress distance is the main drive for walking.

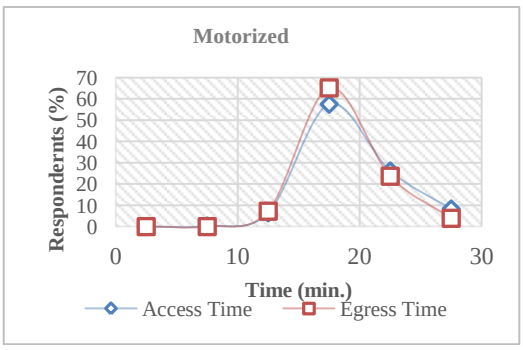



Figure 2. Frequency distribution of access-egress time of walking and motorized mode share

Figure 3, shows the frequency distribution of the access-egress distance in respect of motorized and walking modes. The average access-egress distance is 0.81 Km for walking whereas

the average access and egress distance travelled for motorized mode is 2.45 Km and 2.27 Km respectively.

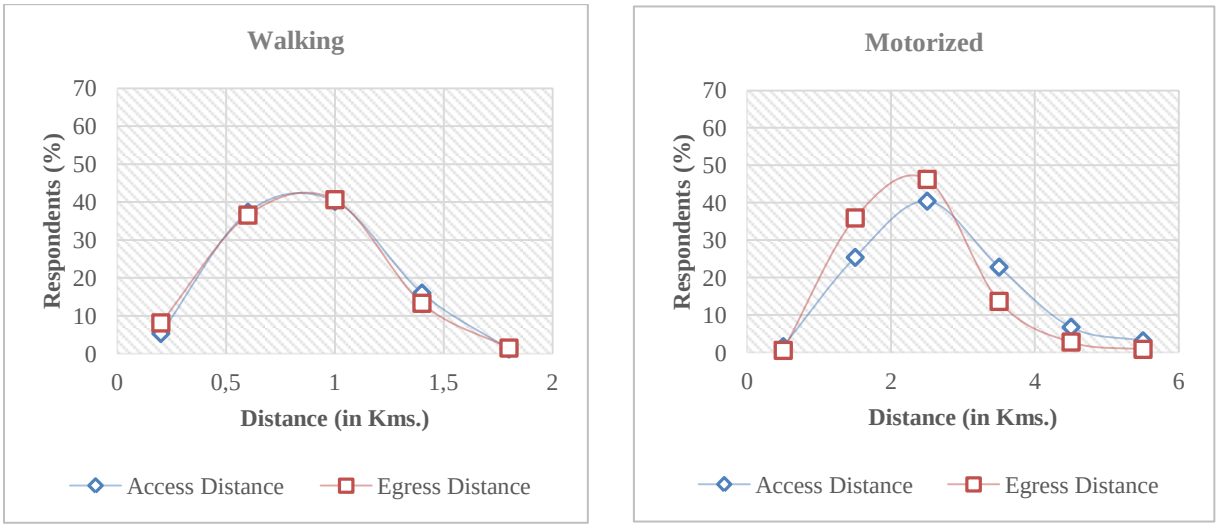



Figure 3. Frequency distribution of access-egress distance of walking and motorized mode share

## 8. ACCESS-EGRESS MODE CHOICE REGRESSION MODELS

In this section, the results of MNL regression models for access and egress mode choice are presented. The predictor variables consider for the regression models include "vehicle ownership", "is sufficient and affordable parking facility is offered by DM at stations", "frequency of the travelling in DM", (generic variables) in addition to access-egress time and distance respectively.

The dependent/response variables analysed are access & egress mode choice respectively. Two models have been developed for access and egress mode choice considering DTC bus as the reference category. The results are shown in tables 4 & 5.

i. In model-1 (Table-4), five categories of access mode (dependent variables) are analysed. The model suggests that access time is highly significant variable for all the modes other than private vehicle. A positive coefficient indicates the likelihood of using that mode for access trip. Since walking has the highest positive coefficient, it is the most preferred mode whereas the feeder bus has least positive coefficient, it is the least preferred access mode due to its limited operations. From the model, it is observed that all others being equal, the preference of access mode considering access time is in the order of walking, E-rickshaw, Auto-rickshaw, DTC bus, feeder bus and private vehicle. The above order of preference confirms the finding that E-rickshaw has replaced Auto-rickshaw to a larger extent as second preferred mode choice and further shift in preference towards E-rickshaw is noted post COVID-19 period.

ii. The model shows that access distance is another significant factor in all access modes other than personal vehicle. A negative coefficient indicates that likelihood of using these modes for access trip decreases in the same order with an increase in the access distance. While, walking is the most preferred for small access distance whereas, DTC bus is most preferred for long access distance. All others being equal, the order of preference of mode choice with increasing access distance is walking, E-rickshaw, Auto-rickshaw, feeder bus, DTC bus. The above order of preference confirms the finding that E-rickshaw has replaced Auto-rickshaw to a larger extent as second most preferred mode choice and further shift in preference towards E-rickshaw is noted post COVID-19 period. This finding is in variation with the findings of (Goel & Tiwari, 2016) which reports that Auto-rickshaw is observed to be second most preferred access-egress mode choice.

iii. Keeping other parameters unchanged and comparing commuters having four-wheeler, the bicycle owners will not prefer walking over other modes. There is a negative significant impact of users with no vehicles with respect to private vehicle.

iv. The results further establish that commuters, who opt walking, don't prefer personal vehicle vis-à-vis parking facility. The predictor variables "Less parking space & unaffordable" and "Less parking space but affordable" are observed to be highly significant among all access mode users other than private vehicle. The positive coefficient shows that comparing with enough parking space and affordable parking facility offered by DM, the parking facility is considered "less parking space & unaffordable" in the order of commuters using feeder bus, Auto-rickshaw, E-rickshaw, walking whereas parking facility is considered "less parking space but affordable" in the order of commuters using feeder bus, walking, E-rickshaw, Auto-rickshaw.

v. Keeping other parameters unchanged and comparing commuters who travel in metro occasionally, have negative

relationship with walking and E-rickshaw. The results indicate that occasional commuters don't prefer walking and E-rickshaw and opt other modes for comfort.

vi. In model-2 (Table-5), five categories of egress mode (dependent variables) are analysed. The model suggests that egress time is statistically significant variable for E-rickshaw, Auto-rickshaw and feeder bus. A positive coefficient indicates likelihood of using these modes for egress trip with respect to DTC bus in increasing order. Since E-rickshaw has the highest positive coefficient, it is observed to be the most preferred egress mode whereas the Auto-rickshaw has least positive coefficient and is less preferred egress mode. From the model, it is noted that all others being equal, the preference of egress mode considering egress time is in the order of E-rickshaw, feeder bus, Auto-rickshaw. It is further revealed that the egress time and distance are insignificant factors only for walking and private vehicle as mode choice. The above results are in variation with the findings of (Goel & Tiwari, 2016; Krygsman et al., 2004) which reports that egress time and distance are insignificant factors for mode choice. This behaviour may be due to micro level study of particular metro corridor with given set of socio-economic and demographics conditions.

| | **Walking** | **E-rickshaw** | **Auto-Rickshaw** | **Feeder Bus** | **Private Vehicle** |
|---|---|---|---|---|---|
| | **Coefficient** | **Coefficient** | **Coefficient** | **Coefficient** | **Coefficient** |
| Intercept | 10.85*** | 8.76*** | 7.79*** | 4.37 | 4.97* |
| Access Time | 2.45*** | 1.23*** | 0.54** | 0.52** | -0.06 |
| Access Distance | -22.32*** | -7.67*** | -3.49*** | -2.98** | -0.13 |
| **Vehicle Ownership** | | | | | |
| No Vehicle | -2.04 | -0.47 | -0.99 | 0.45 | -2.93** |
| Bicycle | -8.49*** | -2.94 | -1.45 | 0.14 | -1.81 |
| Two Wheeler | -1.54 | 0.006 | -0.96 | 1.26 | 0.11 |
| Four Wheeler | 0b | "b" This parameter is set to zero because it is redundant | | | |
| **Is sufficient and affordable parking facility offered by DM** | | | | | |
| Don't need parking facility | 4.23** | 2.1 | 0.424 | -1.21 | -1.04 |
| Less parking space & unaffordable | 19.67*** | 18.98*** | 18.22*** | 16.43*** | 16.30 |
| Less parking space but affordable | 17.31*** | 19.37*** | 19.43*** | 17.14*** | 17.24 |
| Enough parking space but unaffordable | 0.56 | 0.95 | 0.58 | -1.46 | -0.89 |
| Enough parking space & affordable | 0b | "b" This parameter is set to zero because it is redundant | | | |
| **Frequency of travelling in DM** | | | | | |
| Occasional | -3.91*** | -2.39* | -1.59 | -0.24 | -0.89 |
| 1-2 times in a month | 0.99 | -1.34 | -1.69 | -20.68 | -2.98 |
| 4-5 times in a month | -1.14 | -2.53* | -1.88 | -0.80 | -1.44 |
| 2-3 times in a week | 18.53 | 17.93 | 18.86 | 19.09 | 18.07 |
| Daily travelling | 0b | "b" This parameter is set to zero because it is redundant | | | |
| * = P<0.1, ** = P<0.05, *** = P<0.01 | | | | | |
| | ***Model Fitting Information*** | | ***Goodness of Fit*** | | ***Pseudo R-Square*** |
| | ***Intercept Only*** | ***Final*** | ***Pearson*** | ***Deviance*** | ***Nagelkerke*** |
| -2 log likelihood | 1686.143 | 499.973 | | | 0.644 |
| Chi-Square | | 1186.17 | 19365.692 | 487.261 | |
| Df | | 65 | 2615 | 2615 | |
| Significance | | 0.000 | 0.000 | 1.0 | |

Table 4. Multinomial regression model for access mode

vii. The spatial analysis result shows that egress distance is another significant factor in case of E-rickshaw and Auto-rickshaw in respect of egress mode choice. A negative coefficient indicates that likelihood of using these modes for egress trip decreases with an increase in the egress distance. While, E-rickshaw is observed to be the preferred mode for small egress distance whereas, Auto-rickshaw is observed to be most preferred mode for long egress distance.

viii. Keeping other parameters unchanged and comparing with commuters having four-wheeler, the commuters possessing bicycle most prefers feeder bus and having least preference of Auto-rickshaw for egress trip. The commuters owning bicycle prefers feeder bus followed by E-rickshaw, Auto-rickshaw may be due to egress trip fare factor.

ix. The spatial analysis shows that all other variables including parking facility offered by DM and the pattern of the travelling of the users are statistically insignificant and do not contribute to the egress mode choice. Irrespective of captive and choice riders the parking facility in egress trip does not make any impact on the choice of DM as a PT.

| | ***Walking*** | ***E-rickshaw*** | ***Auto-Rickshaw*** | ***Feeder Bus*** | ***Private Vehicle*** |
|---|---|---|---|---|---|
| | ***Coefficient*** | ***Coefficient*** | ***Coefficient*** | ***Coefficient*** | ***Coefficient*** |
| Intercept | 95.83 | 3.38* | 2.55 | -21.21 | 4.49** |
| Egress Time | 58.93 | 1.34*** | 0.47** | 0.57** | -0.05 |
| Egress Distance | -812.67 | -7.66*** | -2.57*** | -2.13* | -1.25 |
| **Vehicle Ownership** | | | | | |
| No Vehicle | 39.49 | 0.11 | 0.075 | 1.34 | 0.51 |
| Bicycle | 167.19 | 19.95*** | 18.57*** | 21.03*** | 19.95 |
| Two Wheeler | 26.75 | 0.18 | 0.36 | 0.64 | 0.76 |
| Four Wheeler | 0b | This parameter is set to zero because it is redundant | | | |
| **Is sufficient and affordable parking facility offered by DM** | | | | | |
| Don't need parking facility | -22.68 | 0.92 | 0.65 | 16.71 | -0.81 |
| Less parking space & unaffordable | 55.34 | 1.52 | 1.17 | 19.61 | -0.57 |
| Less parking space but affordable | 296.72 | 18.13 | 17.17 | 34.84 | 15.45 |
| Enough parking space but unaffordable | -2.89 | -1.03 | -0.71 | 17.06 | -0.66 |
| Enough parking space & affordable | 0b | This parameter is set to zero because it is redundant | | | |
| **Frequency of travelling in DM** | | | | | |
| Occasional | 18.81 | 0.94 | -0.78 | 1.51 | -0.39 |
| 1-2 times in a month | -37.45 | 1.46 | 0.48 | 1.77 | 0.52 |
| 4-5 times in a month | -44.65 | 1.03 | 0.29 | -14.83 | -0.08 |
| 2-3 times in a week | 36.71 | 1.04 | 0.91 | 2.51* | -0.34 |
| Daily travelling | 0b | This parameter is set to zero because it is redundant | | | |
| * = P<0.1 | ** = P<0.05 *** = P<0.01 | | | | |
| | ***Model Fitting Information*** | | ***Goodness of Fit*** | | ***Pseudo R-Square*** |
| | ***Intercept Only*** | ***Final*** | ***Pearson*** | ***Deviance*** | ***Nagelkerke*** |
| -2 log likelihood | 1614.079 | 416.57 | | | 0.487 |
| Chi-Square | | 1197.51 | 1705.057 | 402.47 | |
| Df | | 65 | 2600 | 2600 | |
| Significance | | 0.000 | 1.0 | 1.0 | |

Table 5. Multinomial regression model for egress mode

The above MNL regression results suggest that access-egress time and distance, insufficient and/or unaffordable parking facility influences the access/egress mode choice. The above results shown in table 4 and 5 partially corroborates the findings of previous studies (Goel & Tiwari, 2016), (Krygsman et al., 2004). The regression models reconfirm the influence of socio-economic and demographic conditions along with comfort factors on the access-egress mode choice which further influence the PT ridership post COVID-19 period.

It is inferred that explanatory/predictor variables have more impact on access trip mode choice than egress trip. It is inferred and reconfirm that access mode choice is a dominant factor in post COVID-19 era also to decide the choice of PT over personal vehicle. The regression models explain the access-egress attributes for urban Metro transit riders of BLUE line in Delhi.

## 9. CONCLUSION AND RECOMMENDATIONS

The conclusions drawn from the above spatial-temporal analysis are presented below. It is noted that E-rickshaw has replaced Cycle-rickshaw to a larger extent in Delhi. It is further noted that E-rickshaw has replaced Auto-rickshaw as second most preferred access-egress mode choice and further shift in preference towards E-rickshaw is noted post COVID-19 period.

This finding is in variation with the findings of (Goel & Tiwari, 2016) which reports that Auto-rickshaw is observed to be second most preferred mode choice. The access time and distance are observed to be significant factors in all modes except private vehicle in access mode choice. The egress time and distance are observed to be significant factors in all modes except walking and private vehicle in egress mode choice.

The walking is most preferred access-egress mode comparing other modes which may be attributed to circumvent inconvenience of additional money involved and mode change. These results also substantiate the findings of other studies (Arora, 2019; Goel & Tiwari, 2016; Swami et al., 2013).

The vehicle ownership and travel frequency in DM has limited impact on mode choice for this study of regular and occasional commuters post COVID-19. The parking facility offered by DM is observed to be significant in access trip as some commuters feels that the parking facility is “less parking space & unaffordable” and some feels that it is “less parking space but affordable”. All DM users who use walking as access mode feels that less parking space is available at station and within those there are significant riders those feels that parking charges are unaffordable. These results partially confirm the findings of other research (Habib et al., 2013). The average access-egress walking distance to nearest metro station is observed to be 810 meters. This result confirm the findings of a study (Soest et al., 2020). The average access-egress trip time to reach nearest metro station is observed to be 11.19 minutes and 11.07 minutes respectively which are noted to be more comparing the result of few other studies (Krygsman et al., 2004; Yu & Lin, 2014). This variation may be due to micro level study of particular metro corridor with given set of socio-economic, demographic conditions and higher waiting time because of restricted travel protocols post COVID-19.

The average (access + egress) time and distance are 58.6% and 17.5% of the MHT and MHD respectively. One of the findings

of this research suggests that MHT and MHD are not linearly correlated. Another finding of the research suggest that the access-egress time is not a linear function of access-egress distance respectively due to variation in waiting time of different modes post COVID-19. Considering the analysis results, following recommendations are suggested. A PT system can only be successful if it encourages the commuters to shift from their private vehicle to the PT system (Sharma et al., 2013). An efficient and dedicated feeder bus and/or E-rickshaw service that integrates with the DM with synchronized frequency is required to improve the accessibility and availability. Another important aspect is the integration of all the transit and para-transit modes possibly through a single ticket payment system to minimize the waiting time vis-à-vis access-egress time. Another factor which needs improvement is the development of dedicated pedestrian walking infrastructure to promote non-motorized mode.

## 10. LIMITATIONS AND FUTURE SCOPE OF RESEARCH

The limitations of the study include survey of non-metro commuters and data collection in different weather conditions for further study. The study is limited to the on-board commuters. This survey is conducted in winter and may impact the rider's attributes in other climatic conditions. The following aspects of access-egress time and distance in reference to comfort factors and different climatic conditions, intercity metro impact, fare factors, as future scope of research. The influence of above factors is needed to study on other cities of the country.

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