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Investigating the Trade-off between Transfers and Transit Time in Public Transport: Case Study of Delhi-NCR

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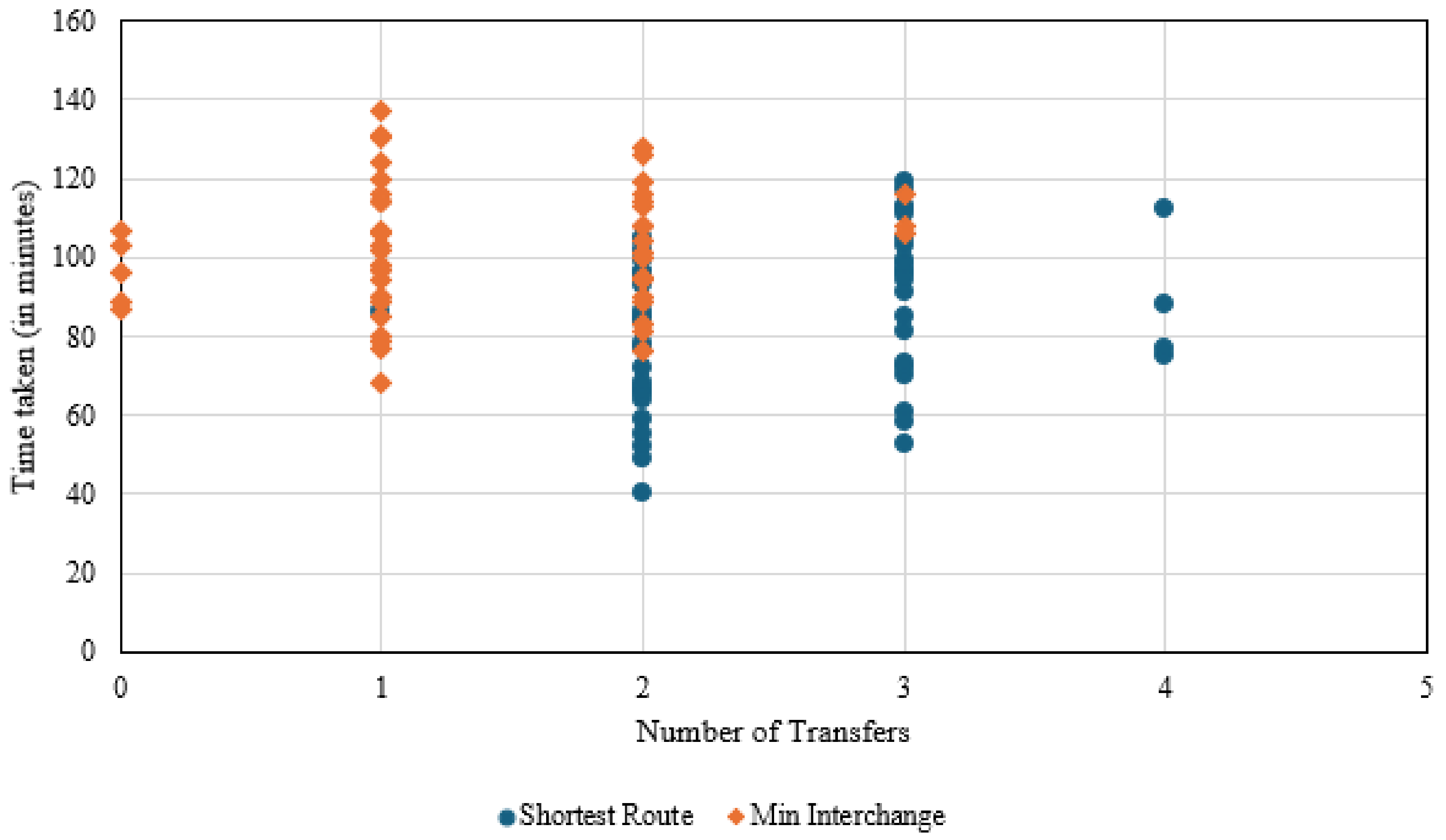
TABLE OF CONTENTS

INTRODUCTION

- Low penetration of buses: 1.32 buses per 1000 people in 2020
- In 2022-23, 63.8% increase in BPKM compared to 2021-22 by IR; yet to attain level of traffic before pandemic
- With rising disposable incomes coupled with extended trips, **ownership of cars has increased**
- Public transport needs to **enhance capacity and simultaneously improve service quality**: access, comfort, frequency, and transit time
- **Two major factors** that govern appeal of mass mobility over personal mobility: **vehicle transfers and transit time**
- Transit time includes time spent inside the main vehicle(s) and on first and last mile
- Bus/train transfers include the number of interchanges made within the PT system (excluding first and last mile interchanges)
- An optimal path may consist of both low transfers and low transit time, or a trade-off could exist between the two depending on several factors
- **Trade-off between transfers and transit time classified into a quadripartite of time, cost, effort and comfort**

RESEARCH BACKGROUND



The Figure shows the cases where the ‘**Shortest Distance**’ and ‘**Minimum Interchange**’ routes are not the same as revealed by DMRC’s journey planner.

This is based on the analysis of the first and the last stations of all metro lines.
Example: Route from Millenium City Centre (Line 2) to Raja Nahar Singh (Line 6) has three alternatives:

- **Transfers – 2** [Hauz Khas (M-M) & Kalkaji Mandir (M-M)]; **Time – 105 min**
- **Transfers – 1** [Central Secretariat (M-M)]; **Time – 114 min**
- **Transfers – 2** [Badarpur Border (M-B), Saket Metro station (B-M)], **Time – 96 min**

What causes trade-off between transfer and transit time?

Primary Characteristics of Transfer & Transit Time:

- Walking Time
- Waiting Time
- Time spent inside the vehicle & outside the vehicle

Research Questions

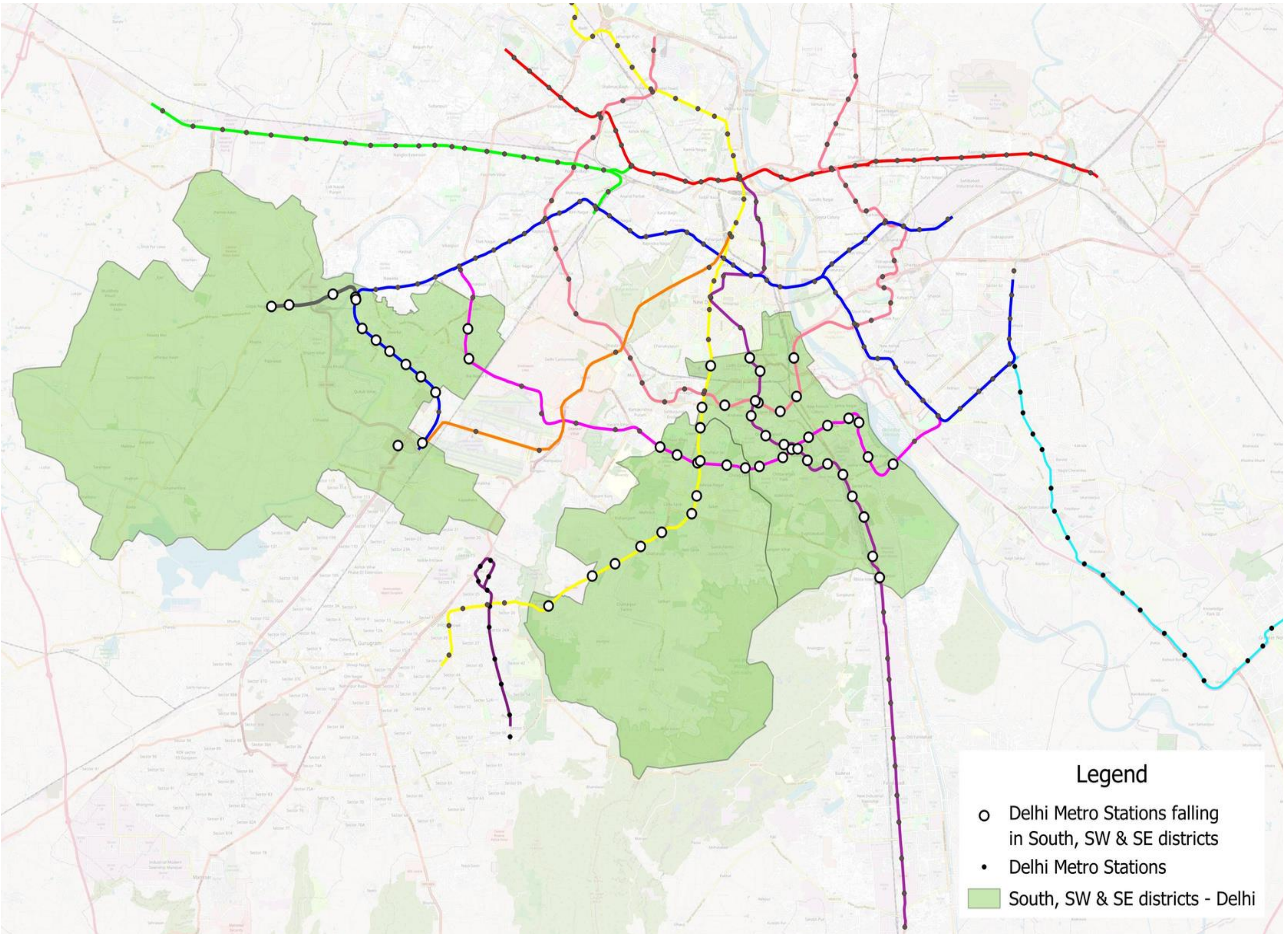
- Does a trade-off exist between transfers and transit time under varying characteristics of in-vehicle time and time spent outside the vehicle for no transfer and transfer scenarios?

- Which factors (like time, first & last mile connectivity, cost, security, real time information, location of initial/final/intermediate stops, crowding, etc.) influence commuters’ perceptions of an optimal path (as a function of transit time and transfers)?

STUDY AREA

- National Capital Territory of Delhi acts the nucleus to several satellite cities and an urban agglomeration with massive scale of urban sprawling and transport activity
- **Interconnected public transport system**: including roads, suburban rail, and mass transit systems comprising of buses and metro rail along with various IPT modes
- Origin and/or destination pairs selected in **three districts of Delhi**: South, South East, and South West districts based on land use type and variation in ridership levels for buses and metro
- Mix of **online and field surveys**

Note: Metro stations and bus stops were selected to understand mobility demand to and from stations/stops in these districts, however, mobility was not subjected to within boundaries of these districts



Metro stations falling under South, South West and South East districts in Delhi

METHODOLOGY

CONCEPTUAL FRAMEWORK

$$P\,(y = 1|x) = G\,(x\beta) \equiv p\,(\mathbf{x})$$

$$\text{Where}\;\; G\,(\mathbf{x}\beta) = \Lambda\,(\mathbf{x}\beta) \equiv \exp\,(\mathbf{x}\beta)/[1 + \exp\,(\mathbf{x}\beta)]$$

$$\mathbf{x}\beta = \beta_1 + \beta_2 x_2 + \ldots + \beta_k x_k$$

01 Stated Preference Surveys

- Tools that assess respondents' preferences to alternatives in specific contexts to estimate their utility functions.
- Alternatives are constructed and presented by the researcher to the respondents' giving them the freedom to choose between factual and/or hypothetical statements

02 Three Scenarios: No Transfer, One Transfer, and Two Transfers

03 Binary Logit Model

Dependent Variable: Binary outcomes (Values 1 or 0)

Error Term: Standard Logistic Distribution

Response probability **[P(y = 1| x)]** regressed on independent variables

DATA COLLECTION

01 Literature Review

Selection of important parameters to delve into tradeoff between transit time and transfers

Construction of Scenarios for Stated Preference Survey

02 Data Collection and Analysis

Secondary Data Collection

- Previous Reports
- Route Information

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- Selection of bus stops/ metro stations
- Selection of sample size

Primary Data Collection

- Survey of commuters

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Broad Parameters of Survey

- Socio-demographic
- Current trip characteristics
- Scenario-based choices

KEY PARAMETERS

Scenarios	Dependent Variables	Scenario specific Independent Variables	
No Transfer	Transfer with reduced trip time but walking/waiting time	Dominant Mode	In-vehicle Time
One Transfer	No Transfer with increased trip time[1]	First Main Vehicle	In-vehicle Time in First Vehicle
	More Transfers with reduced trip time but additional waiting/walking time	Transfer: Walking Time	Transfer: Waiting Time
		Second Vehicle	In-vehicle Time in Second Vehicle
Two Transfers	No or Less Transfers with increased trip time	First Main Vehicle	In-vehicle Time in First Vehicle
		First Transfer: Walking Time	First Transfer: Waiting Time
		Second Vehicle	In-vehicle Time in Second Vehicle
		Second Transfer: Walking Time	Second Transfer: Waiting Time
		Second Vehicle	In-vehicle Time in Second Vehicle

Common Set of Independent Variables

- Numeric
  - Age
  - Household Size
- Categorical
  - Gender
  - Educational Qualification
  - Primary Occupation

Scores from Principal Component Analysis

- Travel Indicators
  - First Mile Connectivity Factors [2]
  - Last Mile Connectivity Factors [2]
  - Trip Duration & Activity Profile
  - Trip Distance
  - First Mile Duration
  - Last Mile Duration
  - Trip Cost
- Important Attributes for Commuters
  - Information Accessibility & Transfer Conditions
  - Commuter Interactions & Safety
  - Transit Reliability
  - Time Efficiency
  - Accessibility & Cost Efficiency

[1] Increase in Trip time has further been segregated into two: a) Increase in only in-vehicle time b) Increase in both in-vehicle and first & last mile connectivity

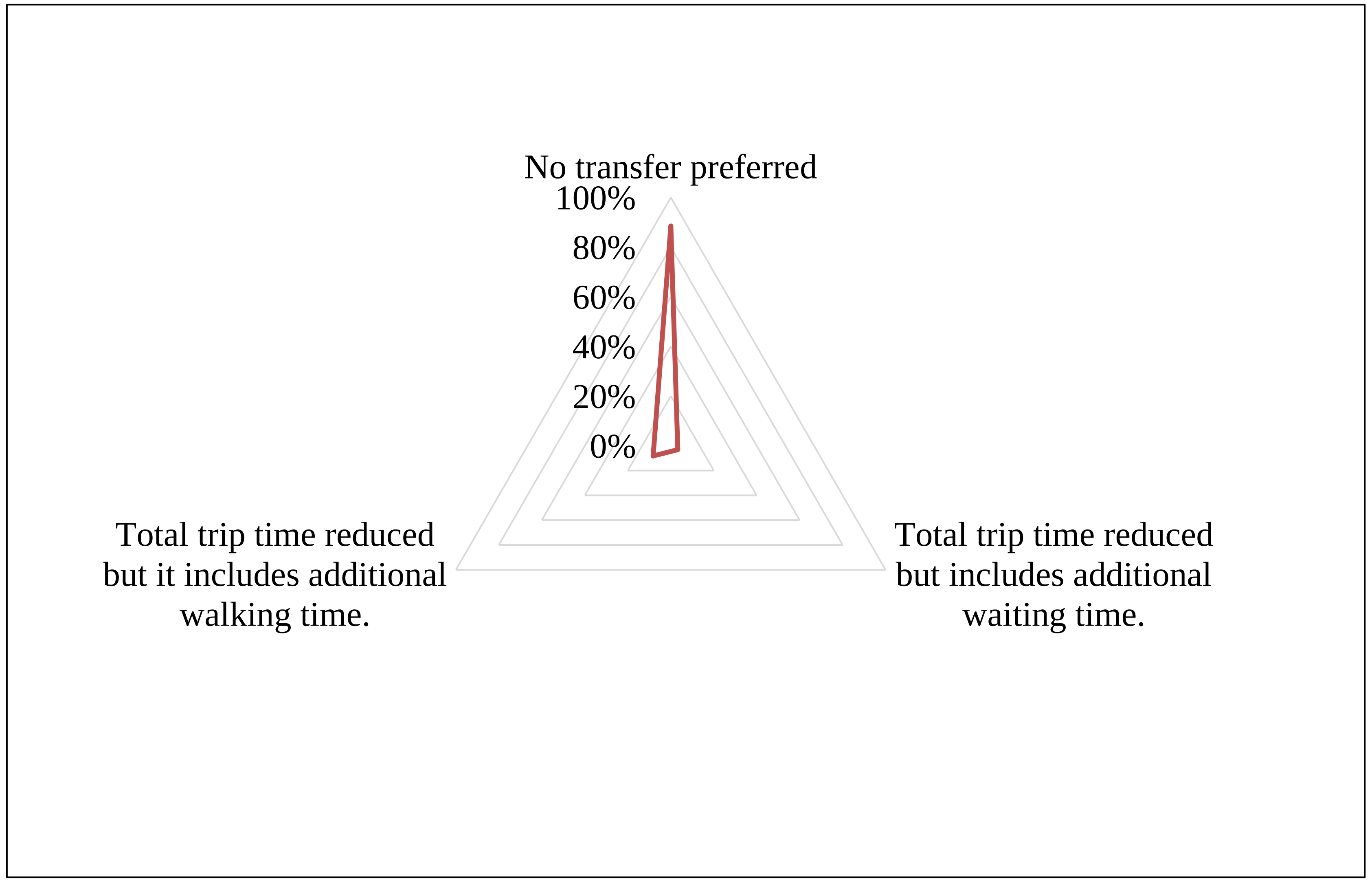
[2] First & Last Mile Connectivity Factors include the components Mode, Distance & Cost (explained in next slide)

PRINCIPAL COMPONENT ANALYSIS

	First Mile Connectivity Factors (component 1)	Last Mile Connectivity Factors (component 2)	Trip Duration and Activity Profile (component 3)	Trip Distance (component 4)	First Mile Duration (component 5)	Last Mile Duration (component 6)	Trip Cost (component 7)
Trip Distance	-0.3243	-0.0182	0.3733	**0.4721**	-0.1412	-0.0173	-0.1431
Transport Expense	-0.3566	0.1245	-0.0771	0.111	0.0667	0.2851	**0.7156**
Trip Time	-0.3591	-0.0637	**0.4011**	0.318	-0.223	-0.1935	-0.0992
Trip Activity	0.0363	-0.025	**0.5328**	-0.5048	0.0025	0.1465	0.2955
First Mile Mode	**0.3932**	-0.2132	0.2451	0.2081	0.2333	-0.0174	-0.0911
First Mile Distance	**0.3778**	-0.1504	-0.0821	0.3975	-0.1534	0.4639	0.0821
First Mile Time	-0.0455	0.4076	-0.2154	0.2614	**0.536**	-0.3905	0.0896
First Mile Expense	**0.3545**	-0.1515	0.2641	0.2513	0.3838	0.0084	0.2285
Last Mile Mode	0.2886	**0.4433**	0.1646	-0.1535	-0.1583	-0.1013	-0.2294
Last Mile Distance	0.2667	**0.3542**	-0.1937	0.2253	-0.5516	0.0005	0.1949
Last Mile Time	-0.1651	**0.4401**	0.0914	0.0297	0.2869	**0.676**	-0.3894
Last Mile Expense	0.1751	**0.4546**	0.3925	0.0292	-0.0426	-0.1555	0.2296

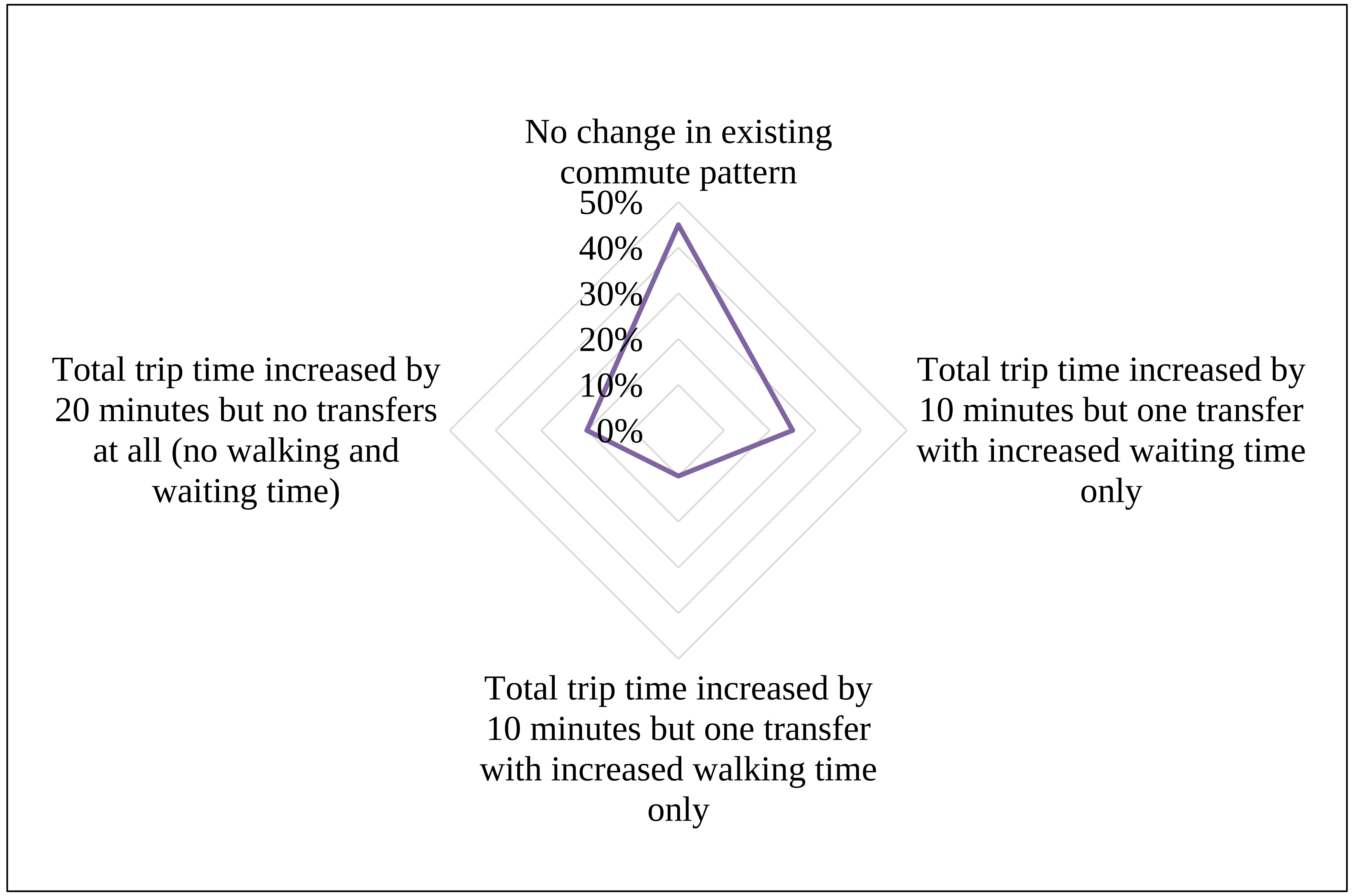
	Information Availability and Transfer Conditions (component 1)	Commuter Interaction and Safety (component 2)	Transit Reliability (component 3)	Time Efficiency (component 4)	Accessibility and Cost Efficiency (component 5)
Availability of real time information	**0.4511**	0.2617	-0.1479	-0.1532	0.2256
Crowding at transfer points	**0.4830**	**0.2791**	-0.2023	-0.0207	0.129
Reliability of arrival and departure times of vehicles	0.2834	-0.3618	**0.3881**	-0.2375	-0.6678
Time saving in reaching destination	-0.1509	-0.2813	-0.6372	**0.5179**	-0.2557
Cost savings	-0.3962	-0.155	-0.2158	-0.6686	**0.2293**
Safety and security	-0.5126	**0.2162**	0.1847	0.0206	-0.0184
Behaviour of fellow commuters	-0.1904	**0.5948**	0.3207	0.2768	-0.1598
Location suitability of the stop/station/transfe r point	0.0643	-0.4681	**0.4439**	0.357	**0.5853**

RESULTS



No Transfer Scenario

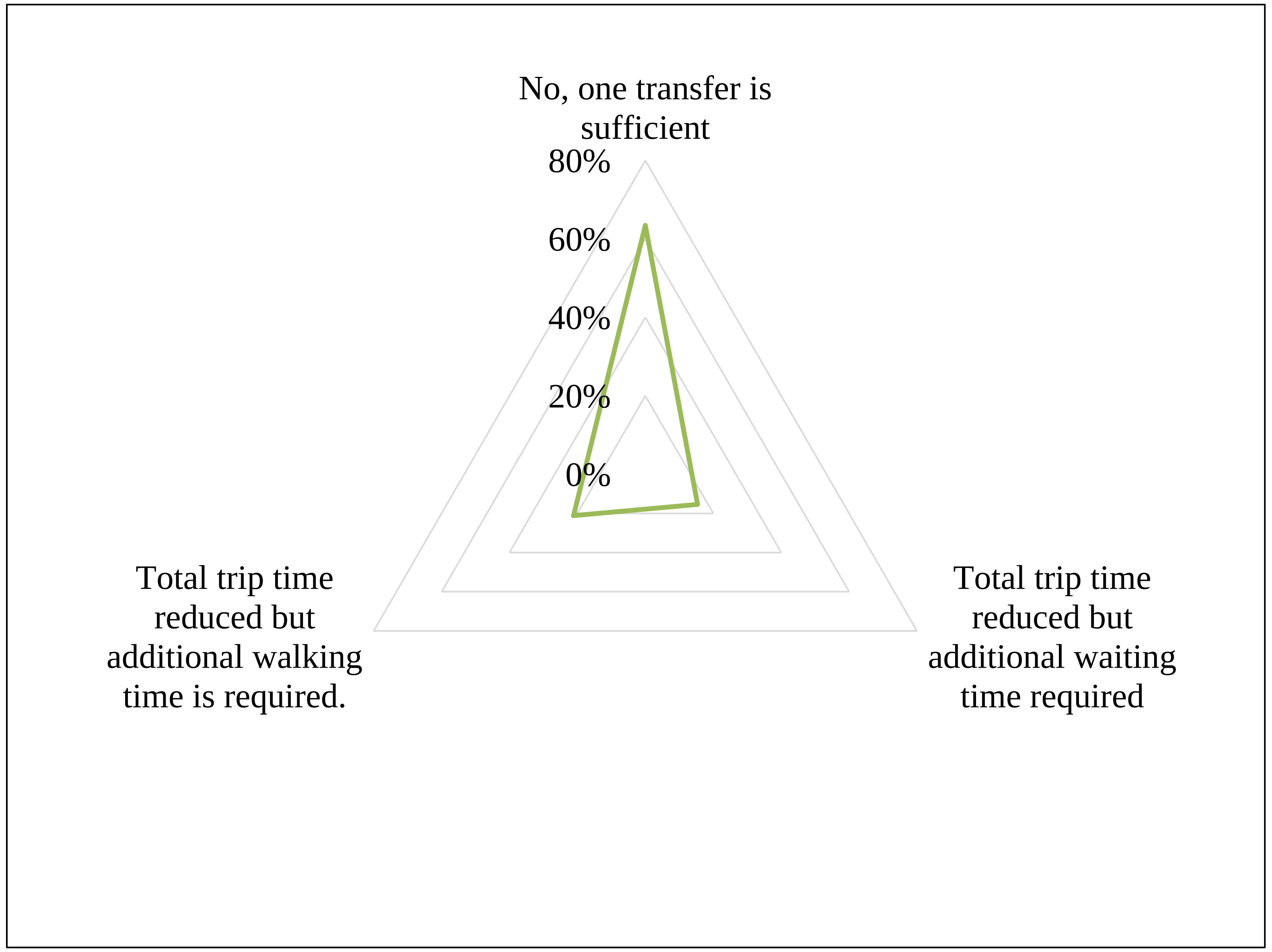
- Majority prefer to stay put in their way
- **56% of the respondents incurring no transfers used bus as their mode of commute.**
- Percentage of respondents preferring additional walking time is higher than additional waiting time.
- Current average waiting and walking times in one transfer are almost equal (6-7 minutes)

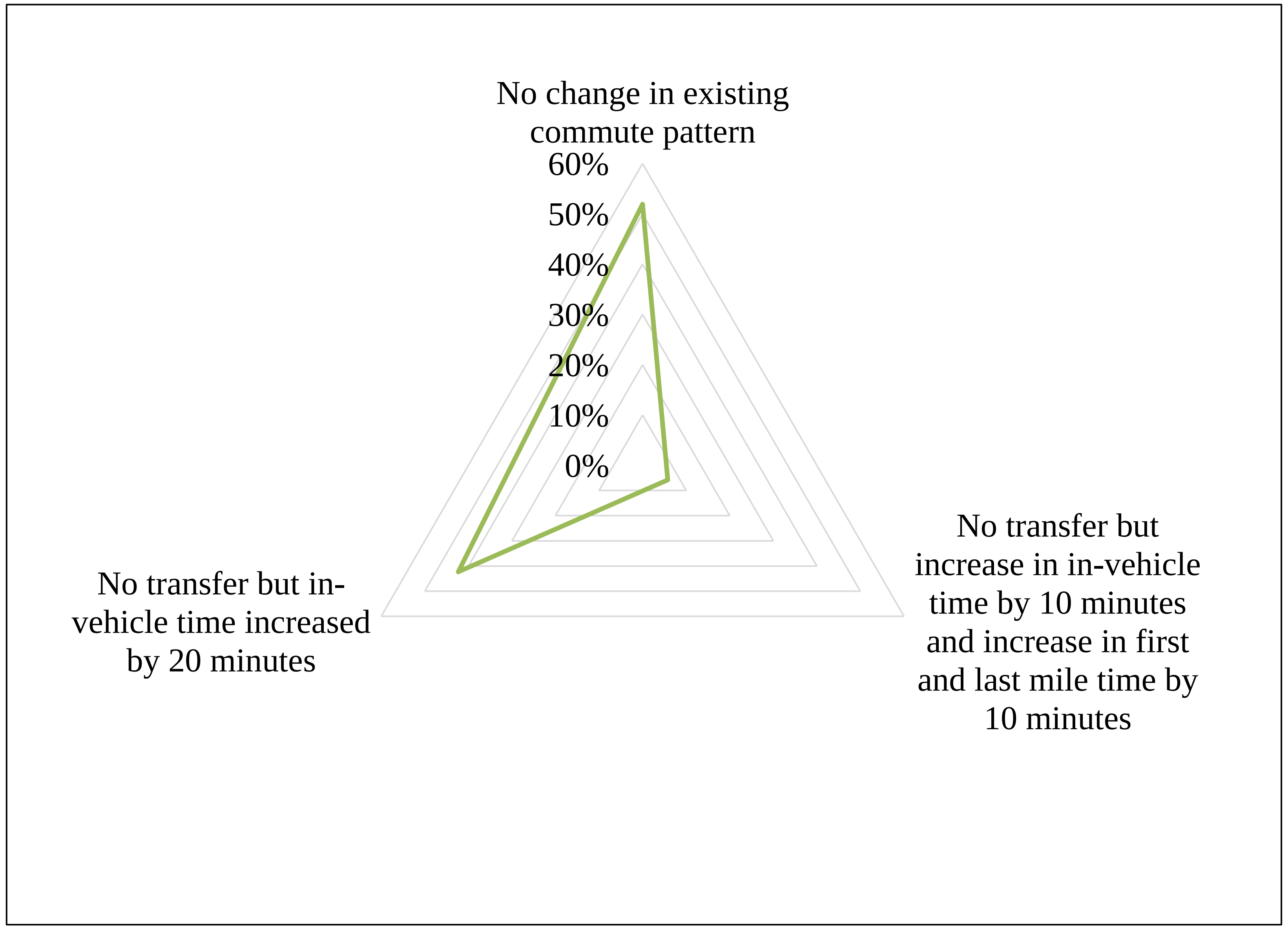


Two Transfers Scenario

- Majority likely to stick to their existing pattern of commute because of familiarity
- Next preferred choice (25%) - Incur one transfer with additional waiting time provided that **the trip time is increased only by 10 minutes.**
- Least preferred - Shift to one transfer with additional walking time. As the number of transfers increase, **commuters tend to associate higher disutility to additional walking time as compared to additional waiting time.**

RESULTS





One Transfer Scenario

- **Inertia** observed in **52%** of the respondents who did not wish to incur less transfers at the cost of increased transit time.
- **42%** willing to shift to **no transfer** provided that **only the in-vehicle time increases**.
- **Only 6%** of the respondents are **willing to shift to no transfer** with increased transit time being reflected in both **in vehicle time and first and last mile connectivity**.

- **63%** would **prefer to stick to one transfer only** and not incur more transfers.
- **21% and 15%** of the respondents are willing to incur more transfers at the cost of additional walking time and waiting time, respectively.
- For shifting from one to more transfers, the **gap** between commuters preferring additional walking time over waiting time **reduces**

RESULTS

Socio-Demographic Characteristics

- Average HH size – 4.3; Average Age – 30 years
- **Average Expenditure on Transport per trip (one-way) – INR 52.39** [Found to be higher for women]
- Educational Profile: Postgraduate & Above (45.5%); Graduate (39.8%); Up to Class 12th (11.4%); Below 12th (3.3%)
- Occupation: Majority – Private salaried (60.7%) followed by Student/Researcher (26.5%)
- Gender Distribution: **49.8% F; 50.2% M**

Salient Features of First & Last Mile Connectivity

<table>
<tr><th rowspan="2"></th><th colspan="2">Mode</th><th colspan="2">Distance</th><th colspan="2">Time</th><th colspan="2">Expenditure (INR)</th></tr>
<tr><th>First Mile</th><th>Last Mile</th><th>First Mile</th><th>Last Mile</th><th>First Mile</th><th>Last Mile</th><th>First Mile</th><th>Last Mile</th></tr>
<tr><td>No Transfer</td><td colspan="2" rowspan="2">Walk/Cycle rickshaw</td><td>Less than 500m</td><td>1 km or more</td><td>Less than 2 minutes</td><td rowspan="2">5 - 10 minutes</td><td colspan="2" rowspan="2">No money spent</td></tr>
<tr><td>One Transfer</td><td>500m to less than 1 km</td><td>More than 500m</td><td>2 - 5 minutes</td></tr>
<tr><td>Two Transfer</td><td>Autorickshaw/ Cab/ Taxi, E-Rickshaw</td><td>Walk/Cycle rickshaw, Autorickshaw/ Cab/ Taxi</td><td>1 km or more</td><td>500m to less than 1 km</td><td>More than 5 minutes</td><td>More than 10 minutes</td><td>More than 40, 20-30</td><td>No money spent, More than 40</td></tr>
</table>

RESULTS

REGRESSION ANALYSIS

- **Last mile duration** found to have **significant positive** impact on **probability** of commuters to **incur more transfers; largely based on delays in egress time**
- **First mile duration** has **positive impact** on probability to **shift to no transfer from existing one**
- **Waiting time** had **positive impact** on shift to less transfers only in case of second transfer; **causing higher disutility with increase in transfers**
- **Positive significant impact of household size** on **willingness** to **shift** from one **to more transfers**; could be with increase in household size, commuters tend to **value time over inconvenience** caused due to transfers
- **Second in-vehicle time** has **negative impact** on **shifting to less transfers** from two transfers

Attributes	No Transfer	One Transfer		Two Transfers
	Shift to transfer	Shift to no transfer	Shift to more transfers	Shift to no or one transfer
Household size	-0.14 (0.25)	0.002 (0.45)	1.66* (0.90)	0.68 (0.52)
Trip duration & activity profile	-0.22 (0.47)	-1.04 (1.47)	---	2.24** (0.92)
First mile duration	-0.68* (0.37)	1.89* (1.01)	-0.14 (0.60)	---
Last mile duration	0.25 (0.51)	0.44 (1.27)	1.62* (0.92)	---
First vehicle mode (Metro)	3.22** (1.54)	-2.34 (3.50)	---	---
In-vehicle time in second vehicle	–	0.04 (0.06)	0.08 (0.05)	-0.05*** (0.01)
Walking time in first transfer	–	0.23** (0.11)	0.19 (0.17)	-0.17 (0.20)
Waiting time in second transfer	–	–	–	0.66** (0.33)
Information accessibility & transfer conditions	0.13 (0.34)	0.33 (0.43)	-1.87** (0.75)	---
Time efficiency	0.18 (0.47)	0.49 (0.53)	-1.29* (0.78)	---
Constant	-0.72 (4.67)	5.39 (7.28)	-9.87 (7.63)	-4.12 (5.13)
	Chi squared= 32.40 (Sig. = 0.0281)	Chi squared= 39.08 (Sig. = 0.0194)	Chi squared= 34.88 (Sig. = 0.0145)	Chi squared= 34.88 (Sig. = 0.0145)
	Pseudo R^2 = 0.3727	Pseudo R^2 = 0.4830	Pseudo R^2 = 0.5109	Pseudo R^2 = 0.5109

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-- Omitted due to multicollinearity

DISCUSSION

High level of inertia in public transport users to shift to alternatives within public transport system

"Adherence to alternatives that have already been used"

- Bovy & Stern[3] (1990)

"Commuters evaluate alternative once when they change home or work address, and then just stick to this chosen mode unless they have a very bad experience with the mode or other major changes occur"

- Windervanck & Tertoolen[4] (1998)

'Metro – Metro' transfers are found to be easier as compared to 'Bus – Bus' and 'Bus – Metro/ Metro – Bus' transfers

Understanding signs and instructions is easier in case of 'Metro – Metro' transfers

Walking Time vs Waiting Time

With less than two transfers, walking time is preferred over waiting time but in case of two transfers, disutility from walking time is increased.

Gupta et al. (2019)[5] in Delhi, India

- Stations like Kashmere Gate, Central Secretariat, and INA had a percentage share of walk mode to be equal or more than 50%
- However, stations like Hauz Khas and Kalkaji Mandir had a percentage share of walk mode to be less than 50%

Garcia-Martinez et al. (2018)[6] in Madrid, Spain

"When making two transfers, the effect of walking time in the second transfer is almost double that of the first transfer."

Need for minimizing walking times in transfers at the end of a trip

[3, 4] Cited in van Exel, Job, and Piet Rietveld. "Inertia of travel behaviour: A stated preference analysis of commuting." In *Transport Developments and Innovations in an Evolving World*, pp. 87-122. Berlin, Heidelberg: Springer Berlin Heidelberg, 2004.'
[5] Gupta, Akshay, G. R. Bivina, and Manoranjan Parida. "How far people can walk to access metro? A study of access trip characteristics of Delhi metro users." In *Proceedings of the Eastern Asia Society for Transportation Studies*, vol. 12. 2019.
[6] Garcia-Martinez, Andres, Rocio Cascajo, Sergio R. Jara-Diaz, Subeh Chowdhury, and Andres Monzon. "Transfer penalties in multimodal public transport networks." *Transportation Research Part A: Policy and Practice* 114 (2018): 52-66.

POLICY IMPLICATIONS

01 Integration of digital infrastructure in terms of information on multimodal public transport services is crucial

Information accessibility and **transfer conditions component** have significant **negative** impact on **probability** of commuters to **incur more transfers** from existing one transfer; Especially in case of buses with lack of information, improper functioning of apps, no designated stops for buses, excessive crowding, perceived risk of delays, missed connections, or uncertainty with increased transfers

Well trained staff can help the elderly, disabled, and children during transfers at key stations like Kashmere Gate (triple line interchange station for metro) and ISBT Kashmiri Gate (key bus terminal)

02 Time efficiency and minimized effort, especially during first and last mile, would lead to increased commuter satisfaction

Delays in **egress times** are found to cause higher disutility as compared to access times.

First and last mile hubs through space allocations with proper signages could reduce the burden of access and egress delays on public transport commuters.

THANK YOU

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