Analyzing of Multimodal Integration of Delhi Metro and Buses Using GTFS Data

Under the Guidance of : Professor Leeza Malik

Team Members

Aadya Dewangan
21JE0001

Shubh Yadav
21JE0907

Shubham Sharma
21JE0909

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Introduction - GTFS

General Transit Feed Specification

Figure Source : https://gtfs.org/

WHAT

It is a standardized data format that provides detailed information about public transportation services like :

routes schedules stops fares

WHEN

TRIMET + Google Portland, Oregon 2005

WHY

1. Enhances Planning & Route Optimization
2. Increases Efficiency By Reducing Operational Delays
3. Promotes Open Data to Foster Public Innovation
4. Improves Accessibility By Increasing Transit Visibility

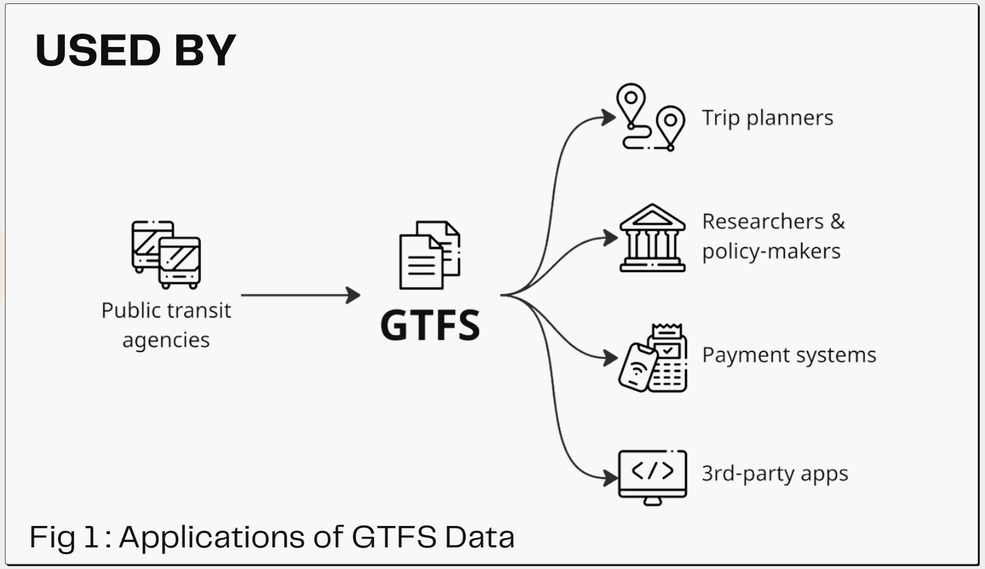


Fig 1 : Applications of GTFS Data

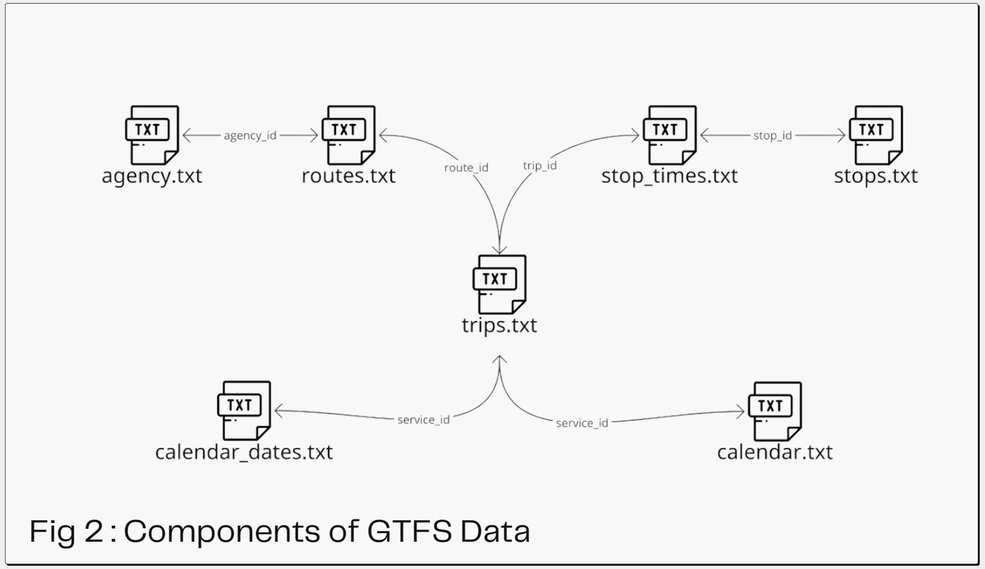


Fig 2 : Components of GTFS Data

Introduction - Multimodal Integration

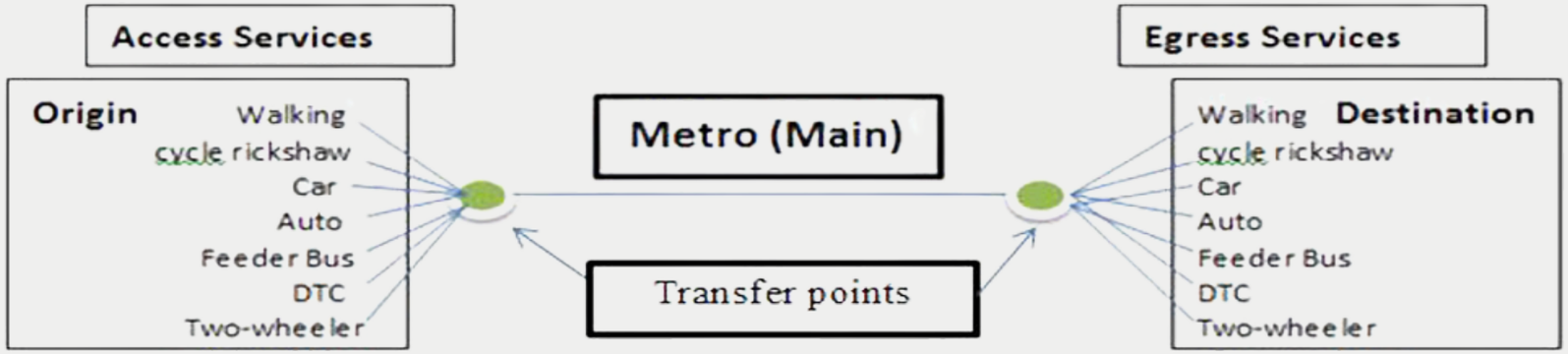


Fig 3 : Multimodal Transportation [2]

Multimodal transportation refers to the integration of multiple modes of transport—such as buses, trains, metros, taxis, and walking—into a cohesive system that facilitates seamless travel from one point to another.

FACTORS

1. Route Rationalization and Bus Feeder Systems
2. Integrated Ticketing
3. Transfer Facilities
4. Land-use Planning
5. Private Vehicle Management

WHY

1. Sustainable Urban Mobility
2. Enhanced Connectivity
3. Efficiency Gains
4. Last-Mile Connectivity

Literature Review

Literature	Title	Major Finding
P. Phani Kumar Dr. Manoranjan Parida Mansha Swami (2013) (Published by Elsevier Ltd.)	Performance Evaluation of Multimodal Transportation Systems.	The analysis shows that multimodal transportation is ideal for longer trips (7.5–35 km), where travel time, access, and egress distances significantly impact efficiency. Improving access, egress, and transfer facilities—such as integrated multimodal transport stations, park-and-ride options, and pedestrian/bicycle paths—can reduce waiting and transfer times, enhancing the appeal and ridership of public transit systems.
Nekzad Umrigar· Jayeshkumar Ramchandrabhai Pitroda (2023) (Published online)	Multimodal Urban Transportation System for Medium Size Cities	Vadodara's urban transport system has made progress with its bus and metro networks, but challenges like congestion, inconsistent schedules, and poor last-mile connectivity hinder its efficiency. Adopting a comprehensive multimodal system—integrating buses, rail, metro, and non-motorized options with improved infrastructure, technology, and policies can enhance connectivity, convenience, and sustainability, meeting residents' needs more effectively.

Research Gaps

1

Lack of User-Centric Performance Metrics

Performance metrics in multimodal studies typically exclude commuter satisfaction and convenience factors.
b) Incorporating user-centric data (e.g., transfer convenience, waiting times) could enhance overall system performance assessment.

3

Limited Real-Time Integration Analysis:

Existing studies mostly focus on static connectivity between metro and buses.
b) Few studies leverage GTFS data for real-time, data-driven analysis to improve dynamic interactions between transit modes in Delhi.

2

Data Quality and Accessibility Challenges

a) Inconsistent data quality and accessibility can hinder accurate analysis and modeling of multimodal systems.
b) Addressing these data-related issues is essential for conducting robust research.

4

Inadequate Focus on Last-Mile Connectivity

a)Current research often overlooks last-mile accessibility, which is crucial for user satisfaction and increased transit ridership.
b)Addressing last-mile gaps could lead to a more comprehensive multimodal transit experience.

Objectives and Scope

Objectives

1. **Evaluate Multimodal Connectivity**
   Assess Delhi Metro and bus integration to enhance accessibility and efficiency.
2. **Analyse Key Performance Indicators**
   Travel Time Ratio, Level of Service, and Interconnectivity Ratio.
3. **Examine Travel Time Elements**
   Impacts of access, transfer, waiting, line-haul, and egress times on overall travel experience.
4. **Optimize Transfers**
   Quantify and reduce transfer times to improve commuter convenience

Scope

1. **Delhi's Multimodal Network**
   Focus on Delhi Metro and buses, with potential future IRBT integration
2. **GTFS Data Utilization**
   Analyse transit schedules, stops, routes, and transfers for seamless multimodal service.
3. **Commuter Travel Patterns**
   Study behavior at key interchanges and along major routes.
4. **Recommendations for Improvements**
   Provide data-driven suggestions to enhance multimodal interchanges and service quality.

Daily Average Passengers (Metro)

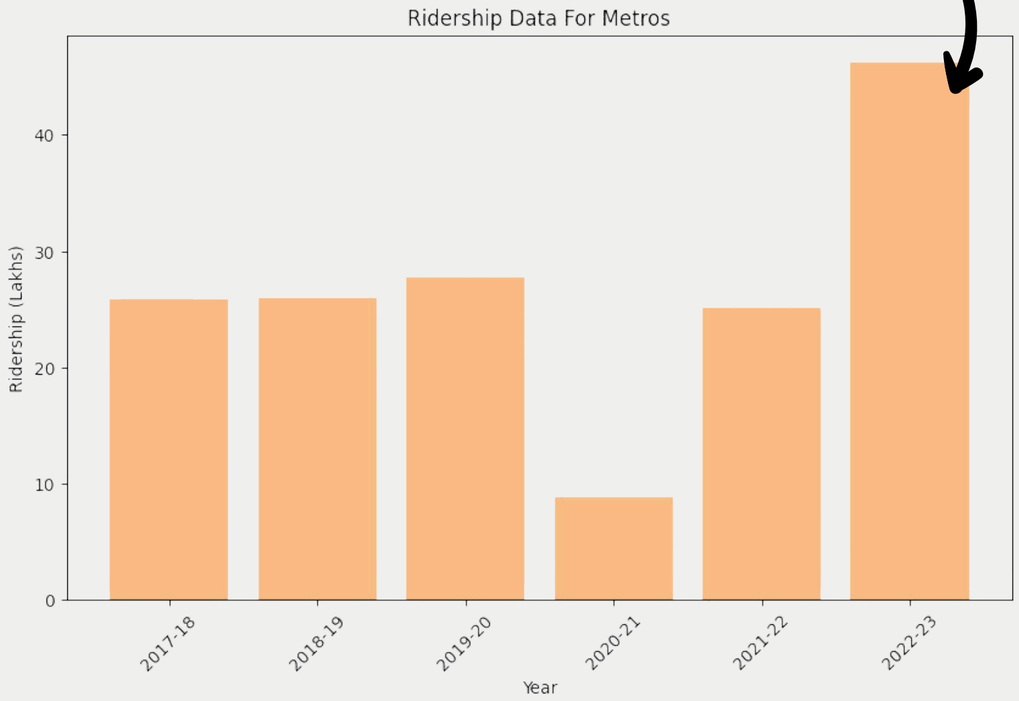


Fig 4 : Daily Average Passengers for DMRC [4]

Daily Average Passengers (Bus)

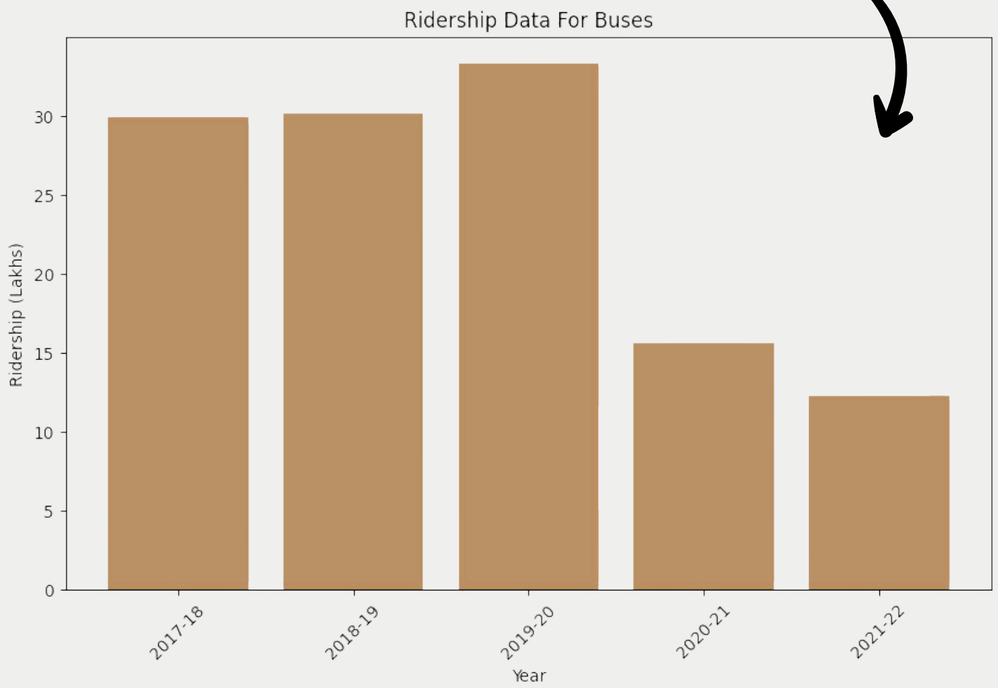
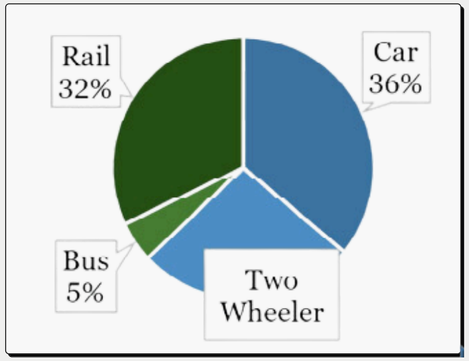


Fig 5 : Daily Average Passengers for Delhi Buses[4]



Share of Public Transport

Fig 6 : Different modes of Transportation used in Delhi[4]

72.38

Lakh passengers travelled in Delhi Metro on August 13.

Methodology

Searching For Data

DATA SOURCE

Open Transit Data BETA DELHI

Static Data of Delhi Buses and Metro

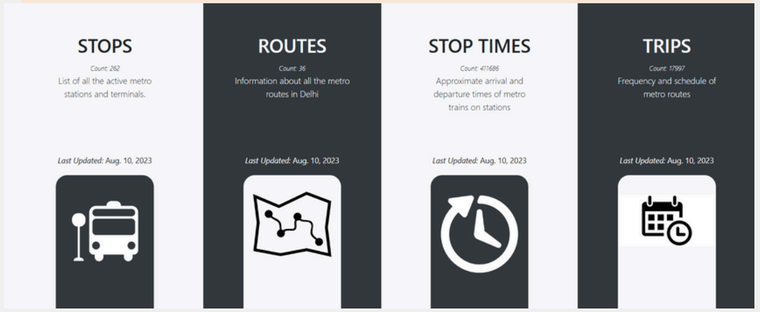


Fig 7 : GTFS Data Inforgraphic[6]

Understanding the Data

The Data Files

- agency.txt
- calendar.txt
- **stops.txt**
- routes.txt
- trips.txt
- stop_times.txt

	stop_code	stop_id	stop_lat	stop_lon	stop_name	zone_id
0	6074EA02	15294	28.416651	77.192307	Jheer Khore Temple	15294
1	1419C9D0	14622	28.417070	77.191505	Jheer Khore Temple	14622
2	1728771C	15295	28.426590	77.189201	Pahari Area	15295
3	D34D7110	15648	28.426609	77.223869	Sanjay Colony	15648
4	DC5642	4802	28.426706	77.223980	Sanjay Colony	4802

Fig 8 : GTFS Data of Delhii Buses– stops.txt

Analyzing the Data

python™

Analyzed bimodal connectivity by mapping bus and metro stops using latitudes & longitudes, and evaluating distances to assess integration efficiency.

```
sns.scatterplot(data=summary_df,
                x='avg_distance_meters',
                y='number_of_bus_stops',
                color='darkblue',
                alpha=0.7)
```

Fig 9 : Code Used in Analysis

Fig 10 : Code to convert .txt file to .csv

```
columns_to_include = ['stop_id', 'stop_name', 'stop_lat', 'stop_lon']

with open(input_file, 'r') as file:
    reader = csv.reader(file)
    headers = next(reader)
    header_indexes = [headers.index(col) for col in columns_to_include]

    cleaned_data = [columns_to_include]

    for row in reader:
        cleaned_row = [row[index].strip() for index in header_indexes]
        cleaned_data.append(cleaned_row)


with open(output_file, 'w', newline='') as file:
    writer = csv.writer(file)
    writer.writerows(cleaned_data)
```

```
def greedy_order_stops(df):
    coords = np.array(list(zip(df["stop_lat"], df["stop_lon"])))
    num_stops = len(coords)

    ordered_indices = [0]  # Start with the first stop
    current_index = 0
    visited = set(ordered_indices)

    # Precompute all distances using a distance matrix
    distance_matrix = cdist(coords, coords, metric='euclidean')

    while len(visited) < num_stops:
        distances = distance_matrix[current_index]
        # Set visited distances to a large number to avoid revisiting
        distances[list(visited)] = np.inf
        nearest_index = np.argmin(distances)

        ordered_indices.append(nearest_index)
        visited.add(nearest_index)
        current_index = nearest_index

    # Return the ordered DataFrame
    return df.iloc[ordered_indices].reset_index(drop=True)
```

Fig 11 : Code to compute distances between stops

The Code

View Source Code

Converted the .txt files to .csv files to so in order to analyse it

Plotted the metro stations and bus stops to visualize it

Used Eucledian Distance to Find Nearest Stops

Visualized the Nearest Bus Stops wrt Metro Stations

```
bus_stops_fig = px.scatter_mapbox(
    bus_stops_df,
    lat="stop_lat",
    lon="stop_lon",
    hover_name="stop_name",
    hover_data={"stop_lat": False, "stop_lon": False},
    color_discrete_sequence=["#00ccff"],  # Light blue color for bus stops
    size_max=2,
    opacity=0.6,
    title="Delhi Transit Map - Bus Stops and Metro Stations"
    )
metro_stations_fig = px.scatter_mapbox(
    metro_stations_df,
    lat="stop_lat",
    lon="stop_lon",
    hover_name="stop_name",
    hover_data={"stop_lat": False, "stop_lon": False},
    color_discrete_sequence=["#ffffff"],  # White color for metro stations
    size_max=10,
    opacity=0.7
)

fig = bus_stops_fig
fig.add_trace(metro_stations_fig.data[0])

fig.update_layout(
    mapbox_style="carto-darkmatter",
    mapbox_zoom=11,
    mapbox_center={"lat": 28.6139, "lon": 77.2090},
    showlegend=False,
    margin={"r": 0, "t": 0, "l": 0, "b": 0}
)
```

Fig 12 : Code to plot the stops on a map

About

Department of Transport (Govt of NCT of Delhi) in association with IIIT-Delhi now publishes transit datasets (static and dynamic/real-time) on Open Transit Data for enterprises, third-party developers, researchers, and other members of the public to promote collaboration and co-creation of innovative and inclusive transport solutions.

Use of Open Transit Data datasets constitutes acceptance of the Open Transit Data Terms and Conditions

Source: https://www.pinterest.com/pin/360780620131576373/

Let's Dive into the Data!

Fig 13 : Plot of Buses Stops and Metro Stations of Delhi NCR Region

262

Metro Stations in Delhi NCR

10559

Bus Stops in Delhi NCR

157m

Average Distance Between Bus Stops

1.67km

Average Distance Between Metro Station

Distribution of Average Bus Stops' Distance from Station

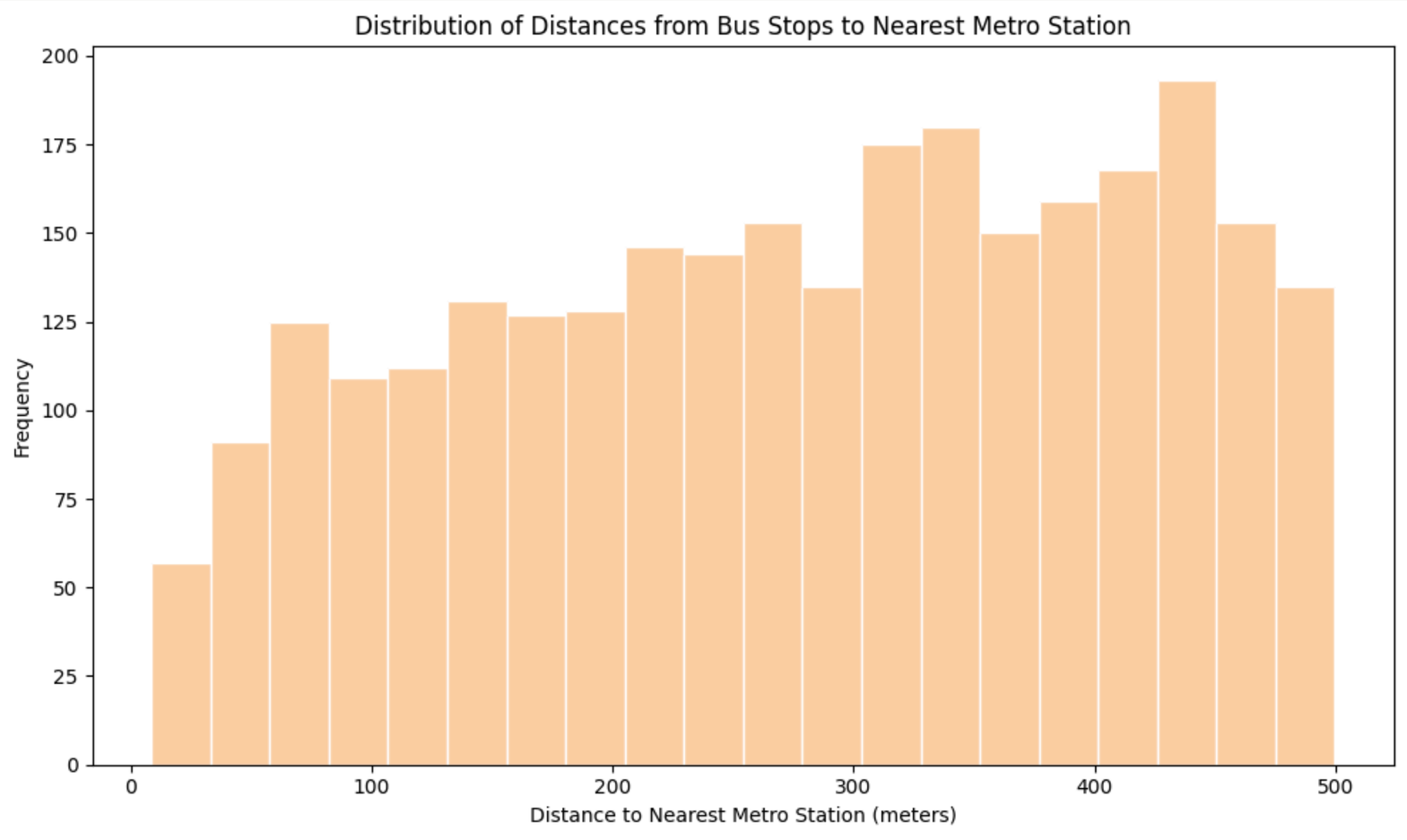


Fig 14 : Distribution of Average Bus Stops' Distance from Station

Results

279m

Mean Distance

289m

Median Distance

133.74

Standard Deviation

28.7%

of the Bus Stops are within 500m of the Metro Stations

Future Scope

Network Optimization

Utilize the data to suggest optimized bus routes or new bus stops that can enhance access to metro stations, reducing the average travel distance.
Implement optimization algorithms (e.g., shortest path, minimum coverage problem) to redesign routes and improve efficiency.

Travel Time Analysis

Travel Time Components:

- Access Time
- Waiting Time
- In-Vehicle Time
- Transfer Time

Scenario Simulations

We can simulate different infrastructure changes (e.g., new metro lines or bus routes) to predict their impact on TTR and IR. This would allow for proactive planning of future expansions, ensuring that changes improve the overall efficiency of the system.

Identifying Problem Areas

Using TTR and IR, we will try to pinpoint areas with high travel time ratios and poor transfer experiences. This data can inform decisions on where to introduce dedicated bus lanes, express services, or improve station accessibility.

References

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8.

Thank you!