Demo of Line-planning tool for Metro

Samay Pritam Singh
Husna Banu
Kalal Karthik

Indian Institute of Technology, Bombay

under the guidance of **Prof. Madhu N. Belur** and

Prof. Narayan Rangaraj

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Problem statement

Line planning for metro systems involves determining the frequency and timing of transport service adapted to dynamic passenger demand, while optimizing for factors such as Avg waiting time of passengers, system capacity, and operational cost

- Its objective is to design optimal metro line plans that meet passenger travel demand while minimizing costs and avoiding overcrowding.
- This problem is important as it impacts both metro operators and passengers by affecting the frequency, speed, and reliability of metro services.

Problem statement

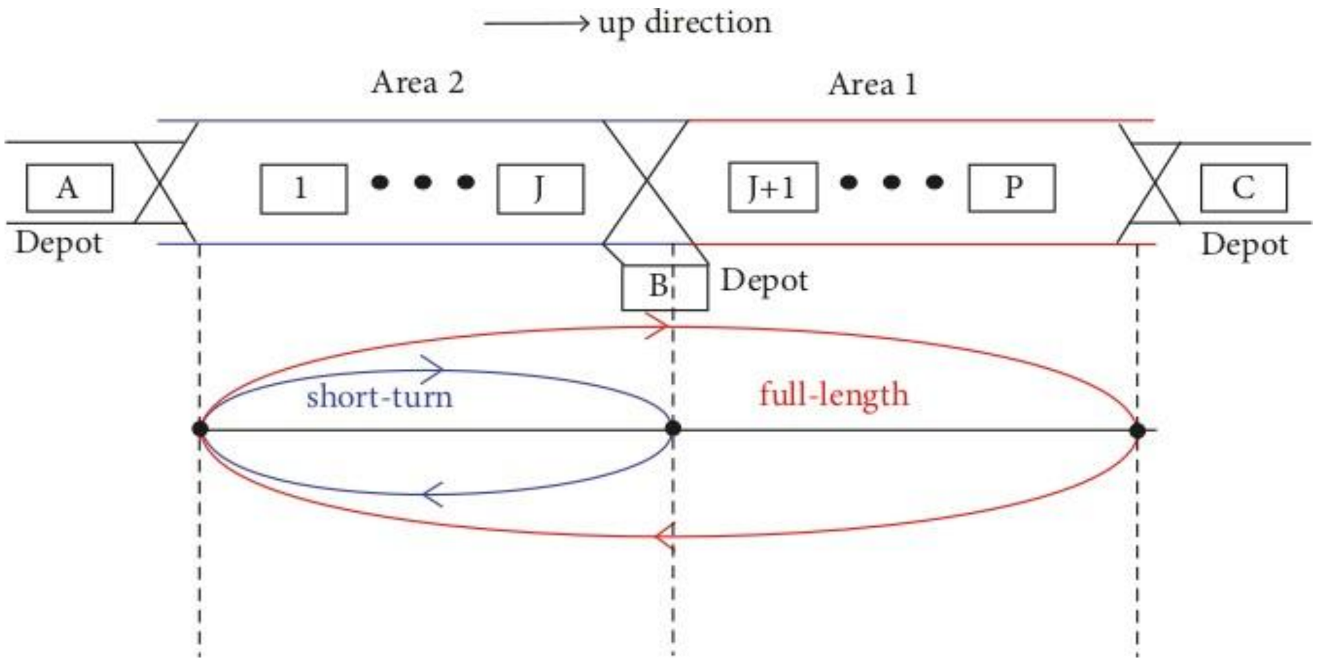

Figure:The layout of urban single-line linear network

Input

Data on daily basis about usage of metro at different times of the day either on a monthly or weekly basis.

- The passenger demand for journeys is given in the form of Origin-Destination (OD) matrix.
- OD matrix is a table that shows the number of trips between each pair of origin and destination zones in a study area
- It is a critical input to line planning tools

Example of Origin-Destination Matrix

	Samaypur Badli	Rohini Sector - 18	Haiderpur Badli Mor	Jahangirpuri	Adarsh Nagar	**Azadpur**	Model Town	GTB Nagar	Vishwavidyalay a	Vidhan Sabha	Civil Lines	**Kashmere Gate**	Chandhni Chowk
Samaypur Badli	0	1255	2707	7071	4464	6244	3026	15261	8781	2067	2015	5342	20825
Rohini Sector - 18	957	0	1301	3742	4164	3544	3877	13851	10388	1838	3200	4823	17977
Haiderpur Badli Mor	2607	1504	0	1427	1303	1720	1847	9108	4307	1263	1183	2609	9174
Jahangirpuri	6809	4252	1467	0	1091	1702	3096	13837	7520	1587	3198	11709	45270
Adarsh Nagar	4261	4217	1429	915	0	689	1473	9542	3874	769	1734	6724	25235
Azadpur	5506	3653	1737	1348	697	0	746	4013	3885	1249	1733	4496	25841
Model Town	2712	3913	1840	2535	1521	531	0	3719	1599	684	1929	4082	20129
GTB Nagar	15079	14109	8560	12439	9467	4540	3418	0	6173	2733	8367	15455	57031
Vishwavidyalaya	7950	9077	3627	6198	3628	3668	1586	5923	0	1502	3653	5735	28280
Vidhan Sabha	2043	2060	1278	1650	866	1436	736	3074	1490	0	859	1239	7685
Civil Lines	1851	2822	1109	2539	1680	1759	2078	9352	4417	1256	0	1864	10024
Kashmere Gate	5248	4067	2287	11349	6261	5080	3586	16379	6299	1430	1893	0	23082
Chandhni Chowk	17577	16067	7680	36869	21275	24044	18427	52699	24687	6459	8840	22280	0

Figure:Example of OD-matrix for DMRC(Yellow-line)

Analysis

Three dimensions of urban transportation demand :

- Spatial dimension
- Temporal dimension
- Direction of traffic

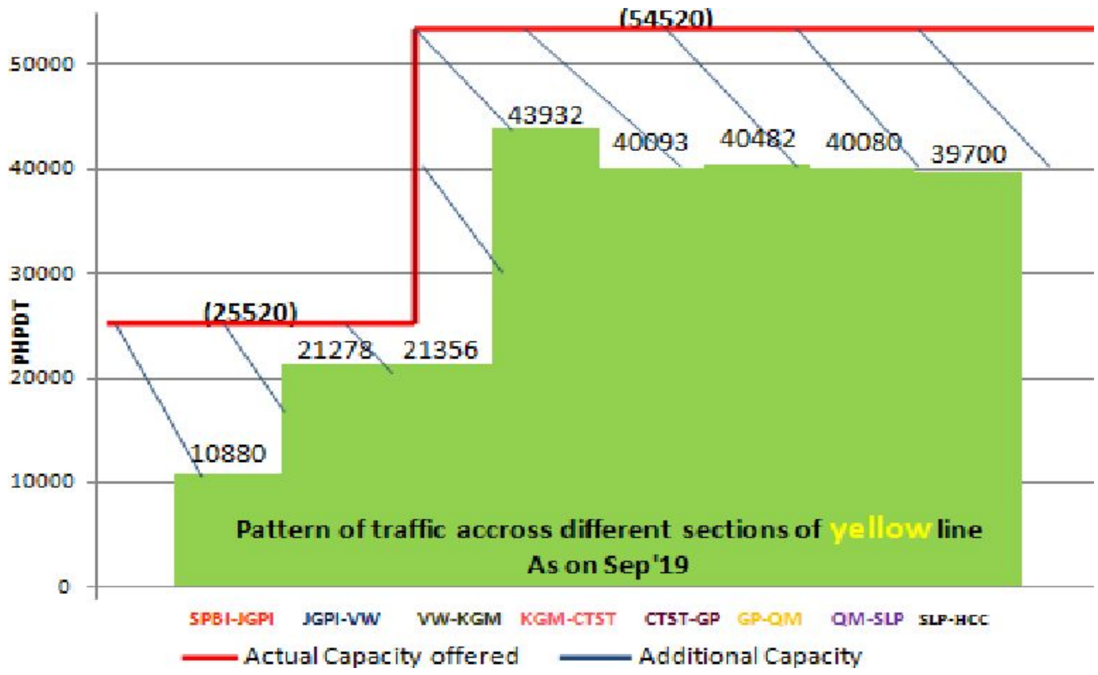

Figure:Spatial variation in demand

Temporal dimension

- Hourly
- Weekly
- Monthly

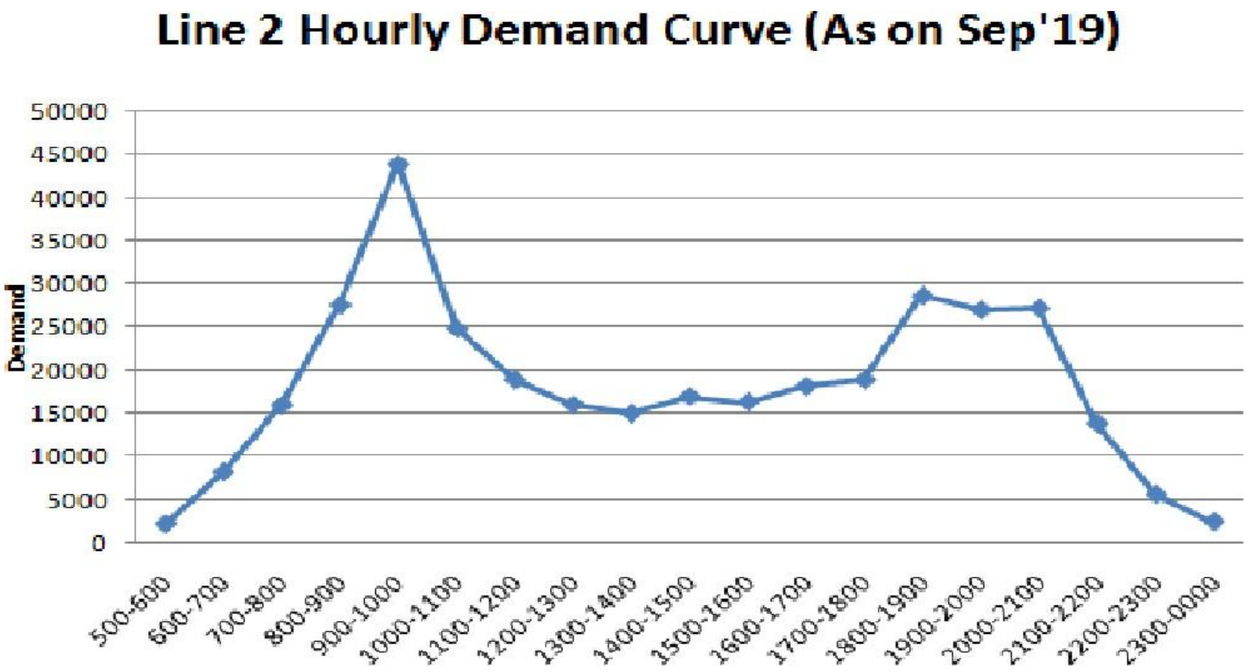

Figure:Hourly demand curve

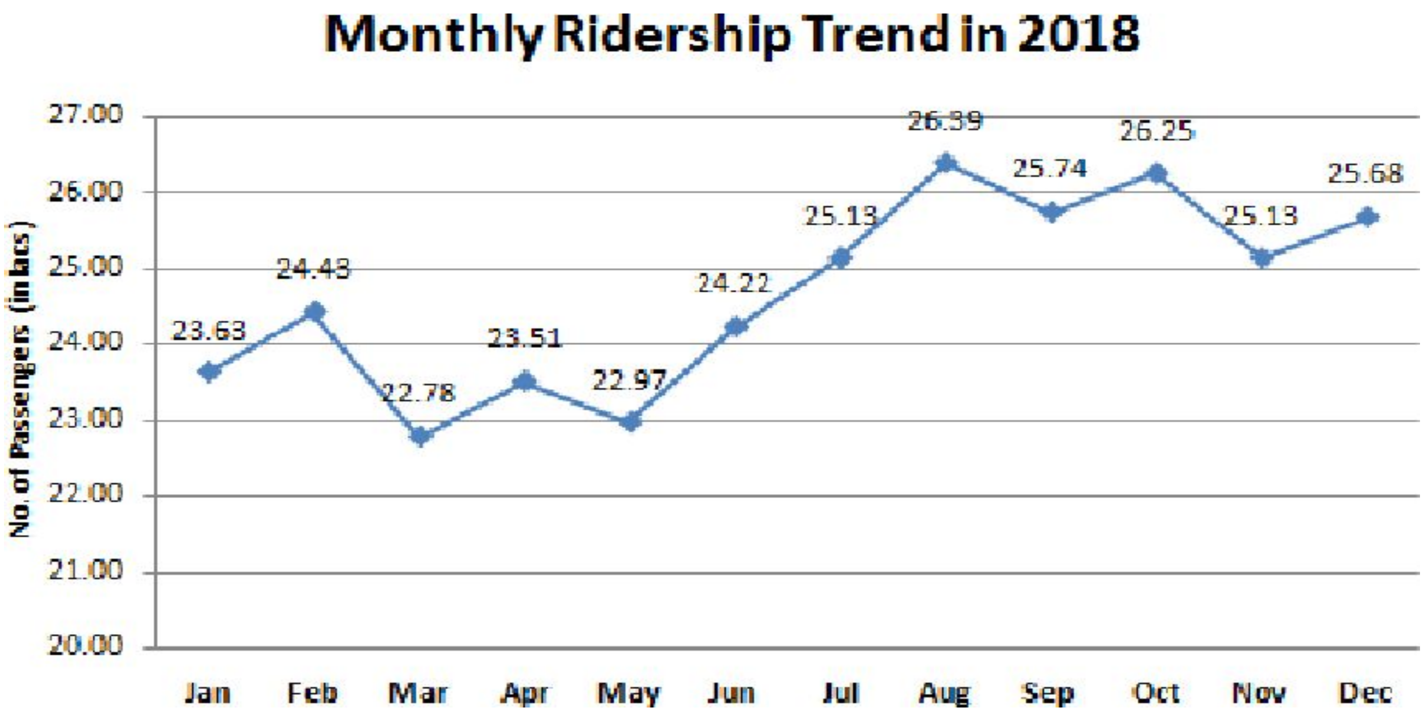

Figure:Monthly ridership trend

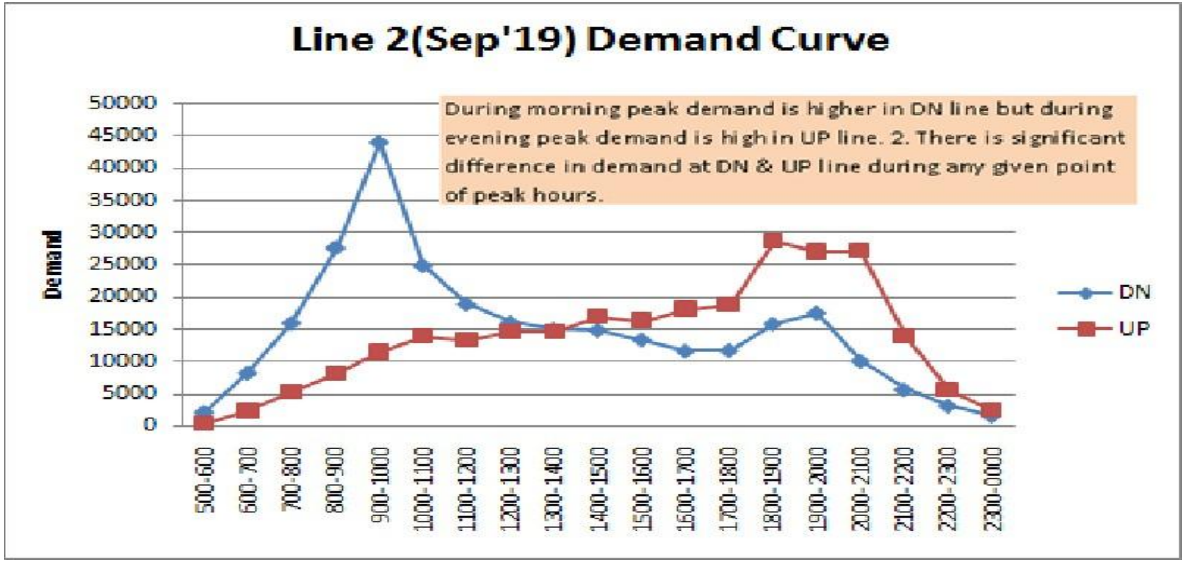

Figure:Hourly and directional demand curve

Some observations made from the above figures are:

- During morning peak hour passenger traffic is highly concentrated towards City Business Centers and Educational institutions. Whereas during evening direction of travel is just opposite.
- Greater number of trains are planned in peak direction and generally the peak direction is opposite for morning and evening peak.

Tool Overview

- The line planning tool is designed using the SimPy framework and uses discrete event simulation to model metro operations.
- Passengers, station and rakes are classes
- Key features and functionalities of the tool include input data preprocessing, line plan optimization, and performance evaluation.
- test different line configurations and strategies to optimize the metro system's efficiency and capacity
- Line planning tool will focus on investigating overcrowding sections and determining specific short turning zones and coordinated schedules.

Performance metrics

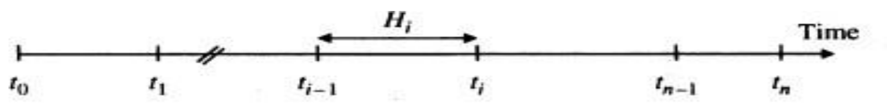

Figure:Operational time span of a metro stop

The variable H_i is the time span between two consecutive train departures, i.e., the departure of train *i* and *i* - 1, expressed as follows:

$$H_i = t_i - t_{i-1}, \qquad t_{i-1} \leqslant t_i$$

the waiting time for a passenger is

$$w = t_i - x, \quad t_i > x$$

The Average value of the passenger waiting time: $t = \frac{H_k}{2}$

Conclusions

- Short turning pattern is an effective method for relieving overcrowding without wasting resources
- Line planning tool will focus on investigating overcrowding sections and determining specific short turning zones and coordinated schedules.
- The tool can use the OD matrix to identify high-demand corridors
- The line planning tool analyzes the OD matrix using various graphs and visualizations to create line plans.
- The tool can use these graphs to optimize line plans by adjusting train frequencies

Future work

- Integrated approach:- Maximizing operator's profit and maintaining high level of passenger satisfaction
- Location based model can be build to minimize the access times to new line
- Once a basic timetable has been prepared based on planned services and frequencies and respecting train operation constraints, dynamic timetabling could be:
    - modification in the medium run based on updated demand information
    - planning for special events that are known in advance (e.g. planned disruptions, or additional traffic at certain known timings, ahead of time)
- Before testing the actual model, the proposed algorithm can be useful for a quick feasibility check.