Demand Analysis

I-Metro: IIT Mumbai

22 March 2023

Dr Amit Kumar Jain

GM CRIS

Structure

- Characteristics of transport demand
- Timetabling to meet the demand
- Transport demand management for Metro systems

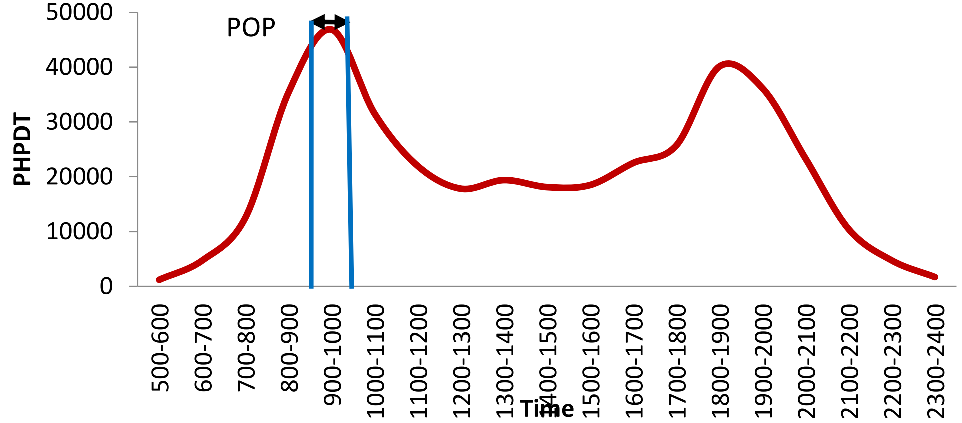
Travel Demand

Passengers per hour per direction (PPHPD)

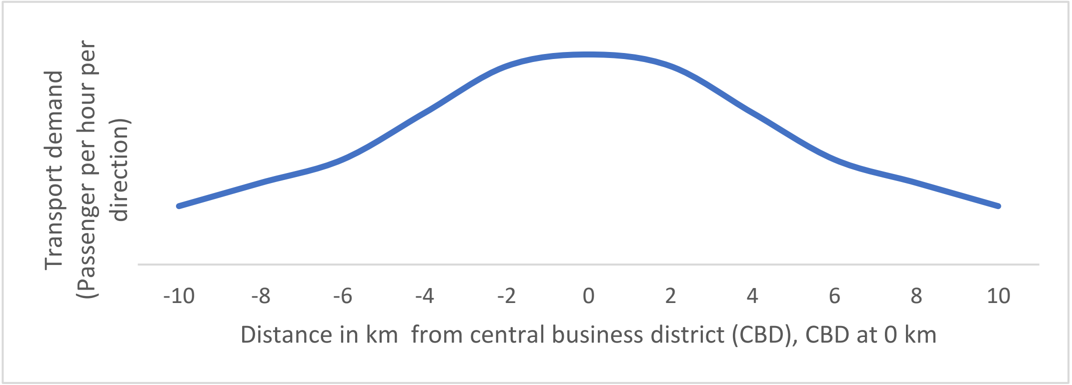
Peak Hour Peak Direction Traffic (PHPDT)

Characteristics of Travel Demand

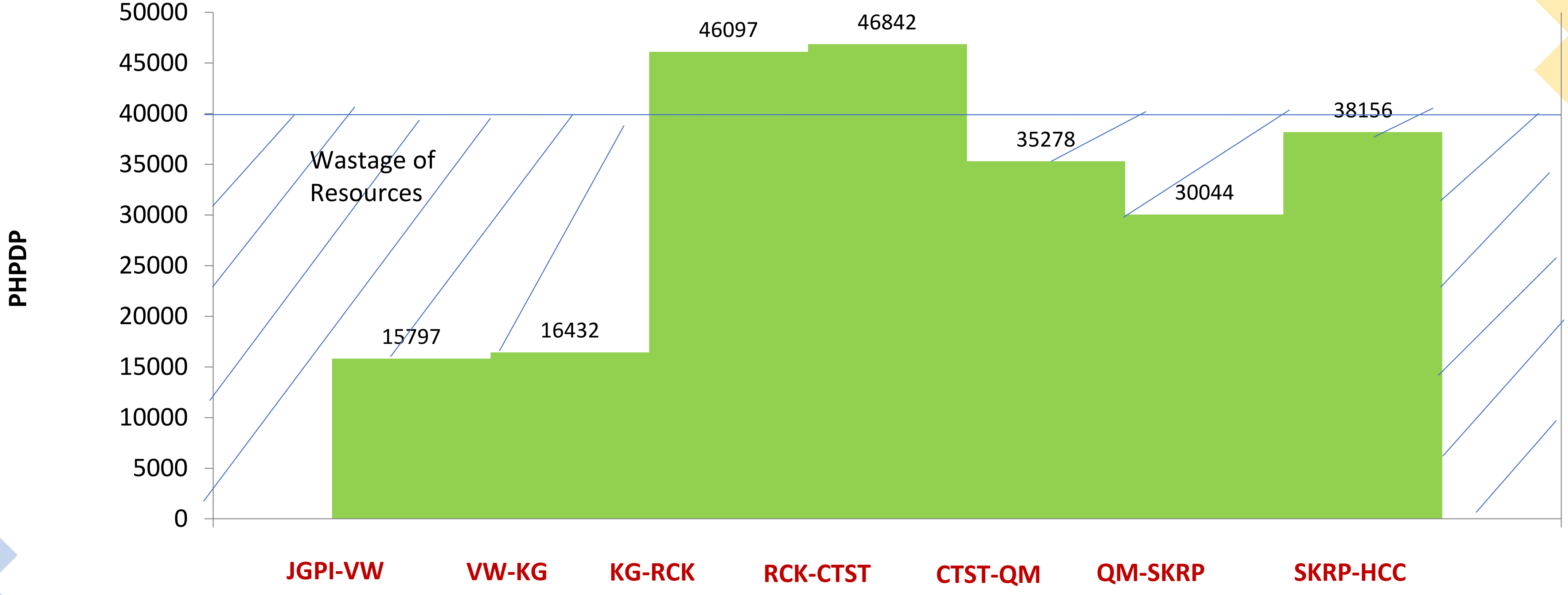
- Temporal Variations



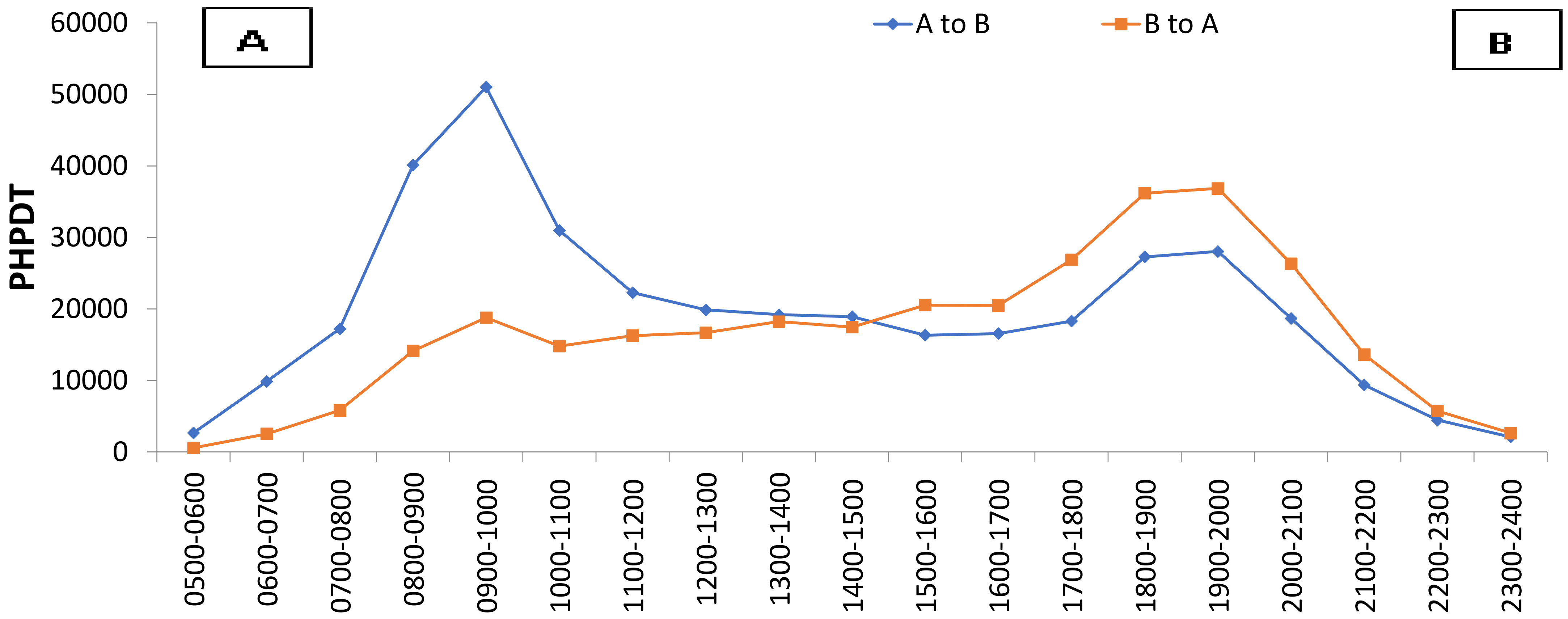
- Spatial Variations



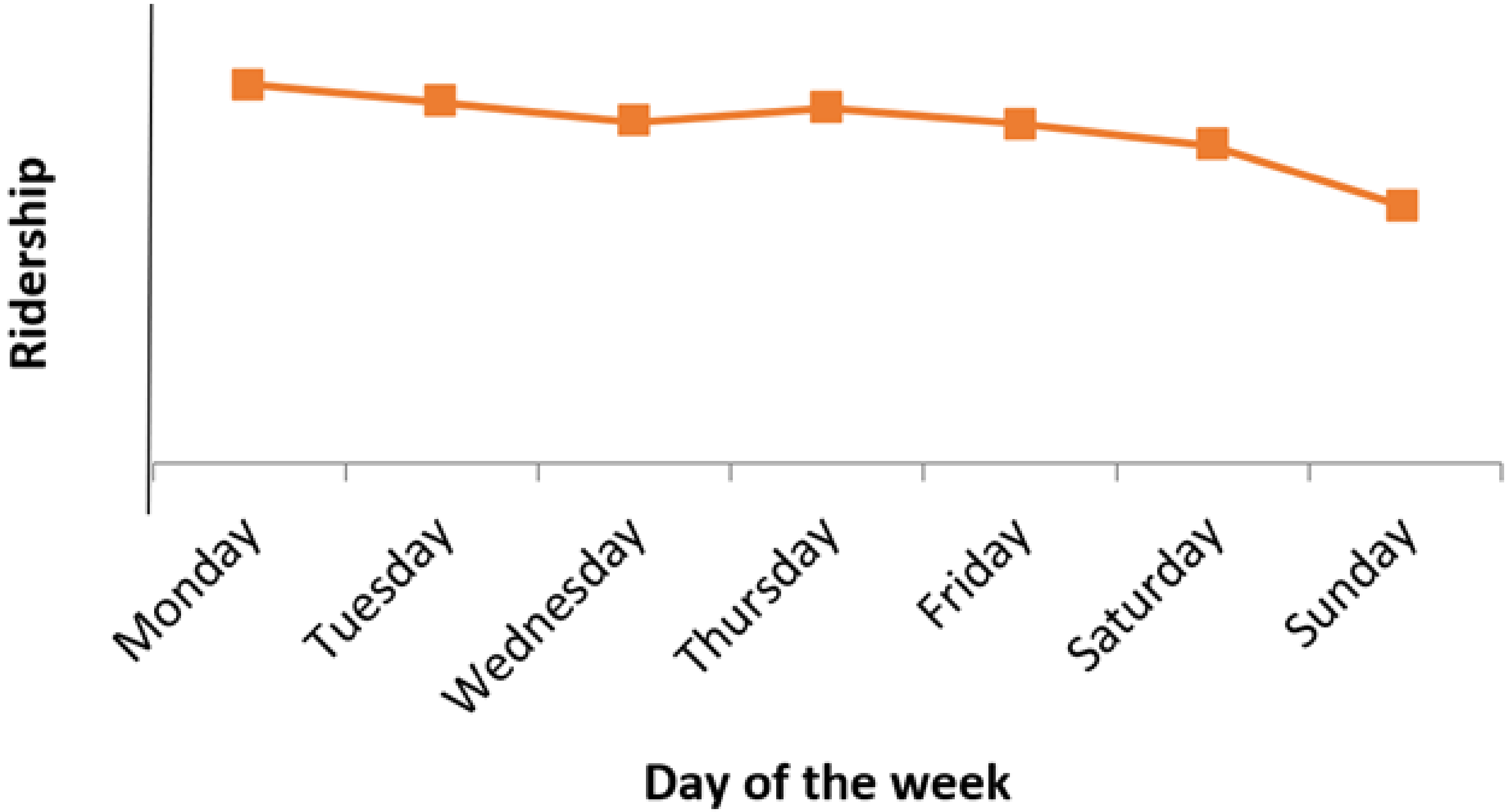
Spatial variation of Demand



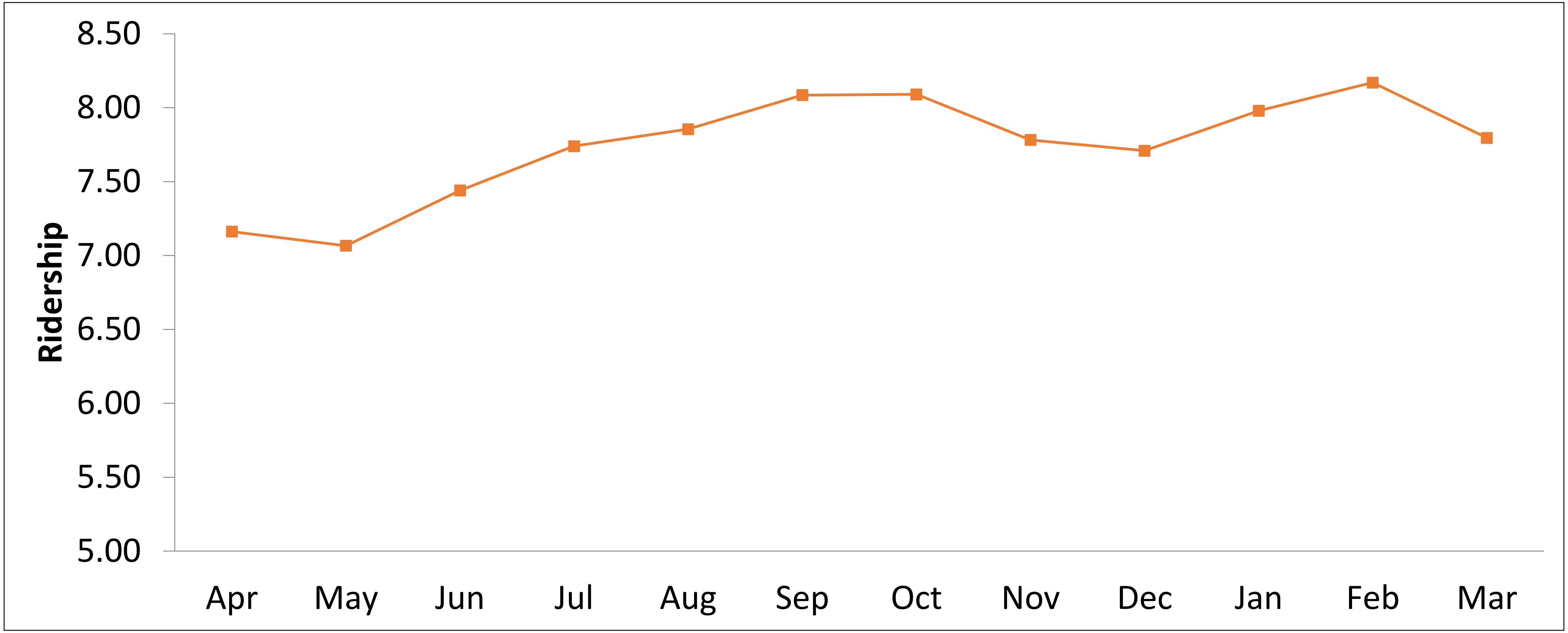
Directional Traffic



Weekly Variation in demand



Monthly variation in demand



Assessment of Demand and congestion

- Automatic Fare Collection system
  - Origin-Destination (OD) data
  - Entry – exit data with time
- Train Load at strategic points
- **Congestion**: Passenger per sqm >6

The Peak Of Peak(POP) Demand

- The maximum demand during the peak of the peak hour is typically 25 % higher than the average of the morning peak period demand.

- The demand typically remains near maximum for a brief period of 15 minutes.

- Peak of the peak demand, is measured in terms of peak 15 minutes per direction passengers ($P_{15}PDP$).

- The timetable designed for PHPDT would result in congestion during the period of maximum demand ($P_{15}PDP$).

- Mostly directional, i.e., in the morning it is in one direction; and the evening peak, though generally flatter, is in the opposite direction.

Special Days

- Gazetted Holidays
- National Holiday
- Festivals
- Exhibition/Mela days

Some important terms

- Frequency
- Headway
- Capacity of the system
- Turnaround Time (Cycle Time) of Operations (Tc)
- Headway required to meet demand
- Requirement of rolling stock

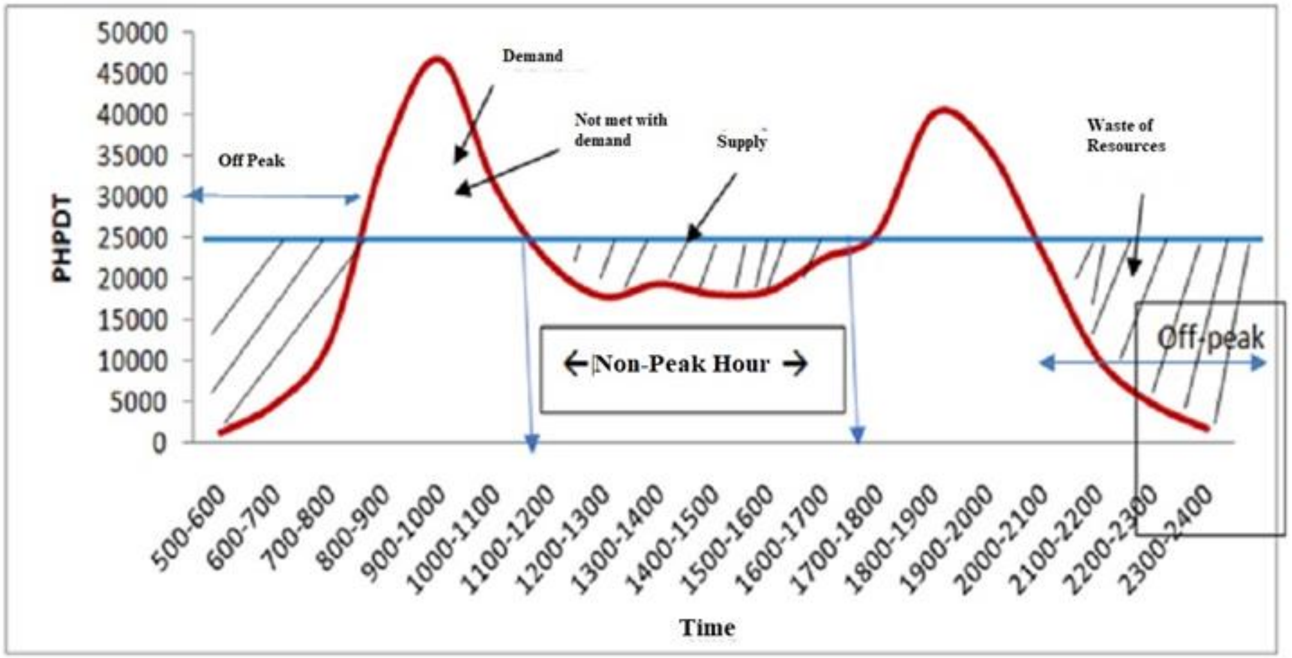
Types of Timetable

- Temporal Variation in demand
  - Uniform Headway
  - Variable Headway

- Spatial Variation in demand
  - End to End operation
  - Intermediate reversal

Uniform headway timetable

- Constant headway over the day except at the start of the day at the end of the day
- Off peak -before start of morning peak hour after finishing evening peak hours.
- Non-peak is time between morning and evening peaks.
- Clock headway or clock face schedule under which train services run at consistent intervals.

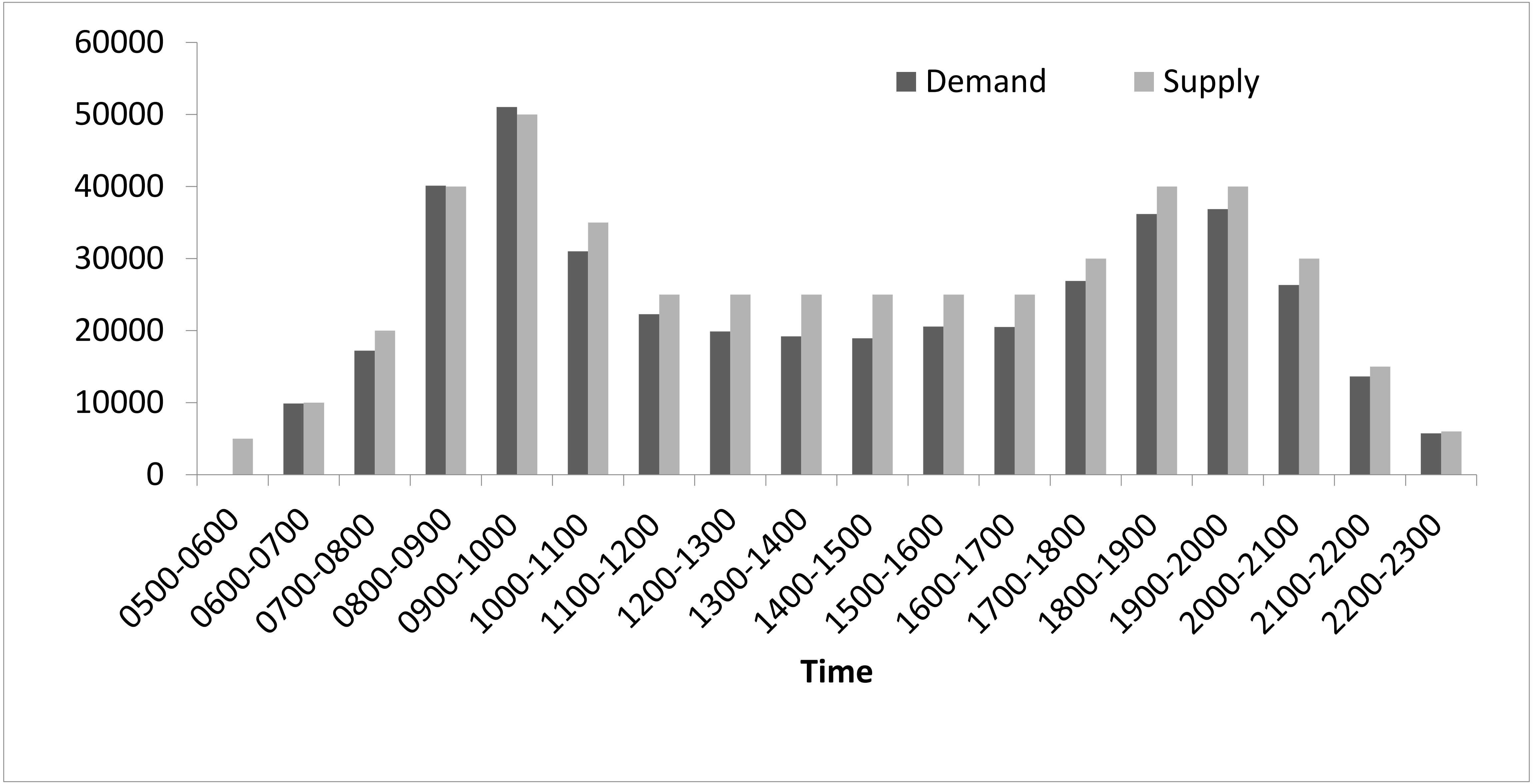


Uniform Headway

- Allow simple information and are convenient to both daily commuters and occasional travellers.
- Minimize waiting times.
- Require simple planning of resources to operate trains such as train drivers, train sets, dispatches of trains from train depot.
- Better level of service during the non-peak hours –attract occasional travelers to use metro train services.
- Inefficient utilization of resourcecs

Variable Headway

- Headway of trains varies over the time of the day as per the demand
- The timetable may be designed to meet P_{15}HPDT or for an average demand during the peak hour (PHPDT).
- Planning to meet P_{15}HPDT will result in the procurement of a higher number of coaches and its ineffective utilisation.
- Challenge is how to exceed supply over the demand to induce increased ridership, as the elasticity of demand for a typical metro with capacity offered (supply) is around 0.5 which means typically a 10 % increase in supply results in a 5% increase in the demand.
- It is advisable to design a timetable for 85%-90% of P_{15}HPDT or average demand during the peak hour (PHPDT), whichever is more to ensure an adequate level of service efficiently.


60000
50000
40000
30000
20000
10000
0
Demand
Supply
0500-0600
0600-0700
0700-0800
0800-0900
0900-1000
1000-1100
1100-1200
1200-1300
1300-1400
1400-1500
1500-1600
1600-1700
1700-1800
1800-1900
1900-2000
2000-2100
2100-2200
2200-2300
Time

Typical ridership during different periods of the day

Period	Period	Time duration	Percentage ridership
5:30 – 8:00	Off-peak	2.30 hours	7%
8:00 - 12:00	Peak (morning)	4.00 hours	31%
12:00 - 17:00	Non-peak	5.00 hours	30%
17:00 – 21:00	Peak (evening)	4.00 hours	28%
21:00 – 23:30	Off-peak	2.30 hours	4%

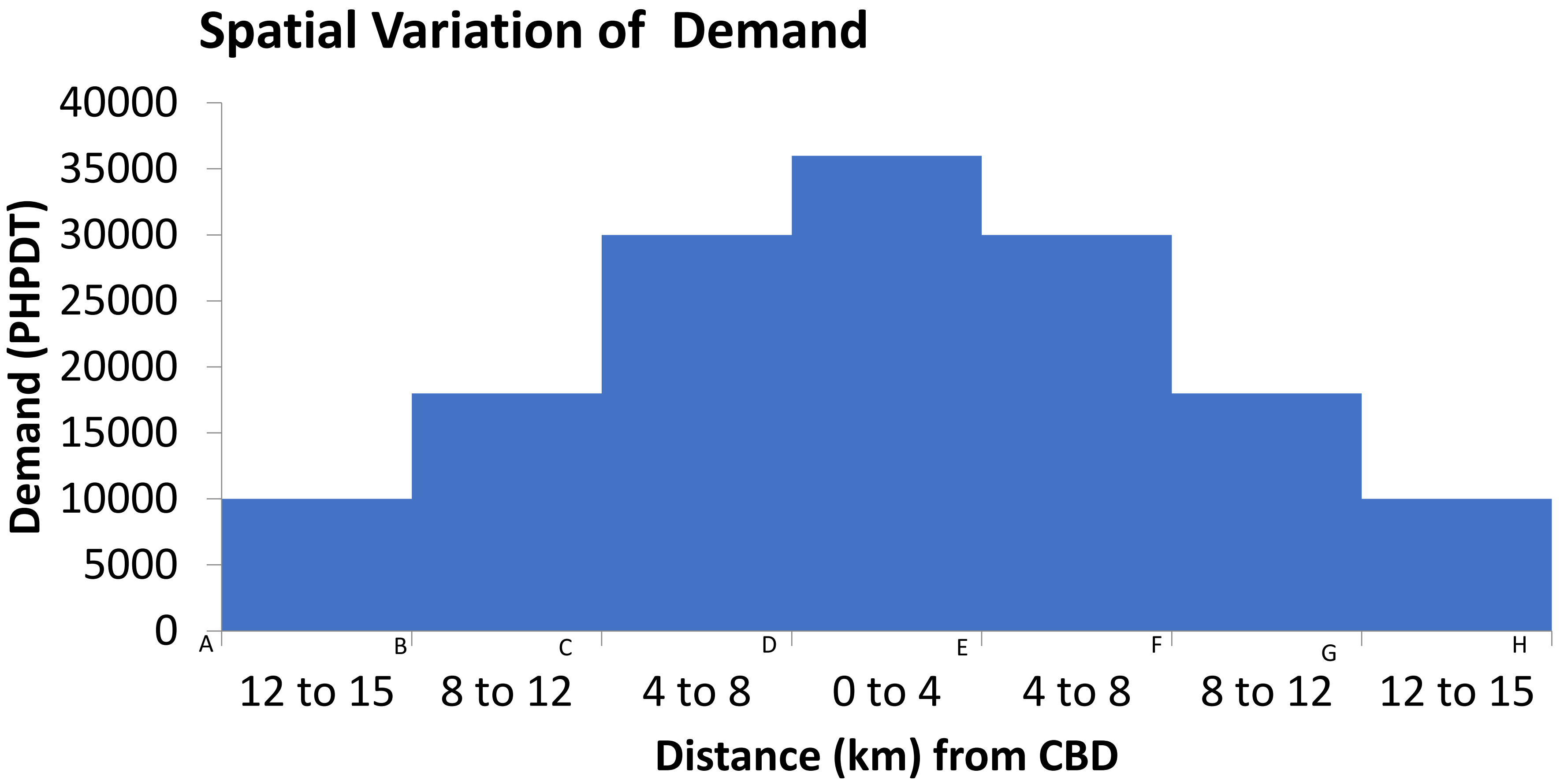
Thus, the demand pattern is as follows:

- Demand during off-peak 5 hours is 11%
- Demand during peak 8 hours is 59%
- Demand during non-peak 5 hours is 30%

Services in Off peak

- The demand during off-peak hours should be analysed to estimate the headway to meet the demand.
- Often there is a demand for more services during off-peak hours but mostly from a very few commuters who have to catch a flight or trains – but without any additional revenue.
- If these services are required to be run for the reasons other than the economical, these could be run in energy conservation mode to contain the expenditure on traction energy for running trains.
- Running these off-peak services, besides causing increased operational expenses, reduce the time available for maintenance of the rolling stock and fixed assets (track, OHE, signalling).
- Kolkata Metro starts services from 10.00 hours on Sundays. Train services commence in new sections of Phase-III of Delhi Metro from 8.00 hours on Sundays, so as mega blocks could be availed on Saturday nights.

Timetable To Manage Spatial Variation In Demand



Type of Operations to meet spatial variation of demand

- End to end Operations

- Intermediate reversal

Headway estimation- end to end operations

- PHPDT = 30,000
- Length of line = 20 km
- Terminal reversal time = 3 mins
- Train composition = 6 car per train
- Per car passengers = 250 (6 pax/sqm)
- Average speed of train = 30 kmph
- Frequency?
- Headway?
- RS requirement?

Headway estimation- end to end operations

- Capacity of train = 6 x 250 = 1500
- Trains per hour to meet demand = 30000/1500
- Frequency (n) = 20 trains per hour
- Headway = 60/n = 3 mins

Fleet size requirement

- Average Speed = v kmph
- End to End Distance = D kms
- Terminal Time = T
- Cycle time =

$$2(D/v+T)$$

- Fleet size required (Fs) =

Cycle time/Head way

- Total Fleet size required (TFs) = Fs + maintenance reqm

Fleet size requirement-End to end operations

- Cycle time = 2 ((20/30) *60 + 3) mins

  = 86 mins
- Required Headway = 3 mins
- Fleet size required (Fs) = 86/3 = 29

- Total Fleet size required (TFs) = 29 + maintenance reqm

Intermediate Reversal

- PHPDT in central part = 30,000
- Length of central part = 10 km

- PHPDT in towards the end of the line = 15,000
- End to end length = 20 km

Frequency and Headway

- Central Part of the line
  - Frequency for central part = 30,000/1500 = 20 trains per hour
  - Headway = 3 mins
- Towards the end of Line
  - Frequency for central part = 15,000/1500 = 10 trains per hour
  - Headway = 6 mins
- Every alternate train may be reversed from the intermediate reversal point
  - Headway of trains in outer loop = 6 mins (10 tph)
  - Headway of trains in inner loop = 6 mins (10 tph)
  - Effective headway in the central part = 3 mins (10 + 10 =20 tph)

Fleet requirement

- Inner Loop
  - Length = 10 km
  - Headway = 6 min
  - Reversal time = 3
  - Cycle time = 2 ((10/30) *60 +3) = 46 mins
  - Trains required = 46/6 = 7.7
- Outer loop
  - Length = 20 km
  - Headway = 6 min
  - Reversal time = 3
  - Cycle time = 2 ((20/30) *60 +3) = 86 mins
  - Trains required = 86/6 = 14.3
- Total trains required = 14.3 + 7.7 =22

Intermediate Reversal-Exercise

- PHPDT in central part = 30,000
- Length of central part = 10 km

- PHPDT in towards the end of the line = 10,000
- End to end length = 20 km

Frequency and Headway

- Central Part of the line
  - Frequency for central part = 30,000/1500 = 20 trains per hour
  - Headway = 3 mins
- Towards the end of Line
  - Frequency for central part = 10,000/1500 = 6.67 trains per hour
  - Headway = 9 mins
- Every two out of three trains may be reversed from the intermediate reversal point
  - Headway of trains in outer loop = 9 mins (6.67 tph)
  - Headway of trains in inner loop = 4.5 mins (13.33 tph)
  - Effective headway in the central part = 3 mins (6.67 + 13.33 =20 tph)

Fleet requirement

- Inner Loop
  - Length = 10 km
  - Headway = 4.5 min
  - Reversal time = 3
  - Cycle time = 2 ((10/30) *60 +3) = 46 mins
  - Trains required = 46/4.5 = 10.22
- Outer loop
  - Length = 20 km
  - Headway = 9 min
  - Reversal time = 3
  - Cycle time = 2 ((20/30) *60 +3) = 86 mins
  - Trains required = 86/9 = 9.56
- Total trains required = 10.22 + 9.56 = 19.78 (20)

Timetabling For Weekly Variation In Demand

- In view of the large variation in demand on weekdays, Saturdays, and Sundays, it is advisable to have different timetables for
  - weekdays,
  - Saturdays,
  - Sundays,
  - National holidays
  - Gazetted Holidays
  - Special Festival days
  - Special event- cricket match
- The spare rakes may be used for maintenance, modifications.

Best practices in Timetabling

- Station Dwell time rationalisation to increase speed
- Outstation stabling of trains
- Real-time monitoring of demand
- Introduction of additional train from intermediate Stations
- Induction of more high-capacity trains (6C trains) in the first half of the week
- The interlacing of high capacity (6C) trains with 4C trains
- Advanced information of train composition on PIDS

Demand Management for metro train systems

Congestion

Problem of Peak hour demand

Peak hour demand 60-70% higher than non peak demand- distinct peak

Heavy congestion during peak hour; partially empty trains during non peak.

Suboptimal utilization of assets if designed for peak hour demand.

Supply side solutions- to increase number of trains/cars during peak hours

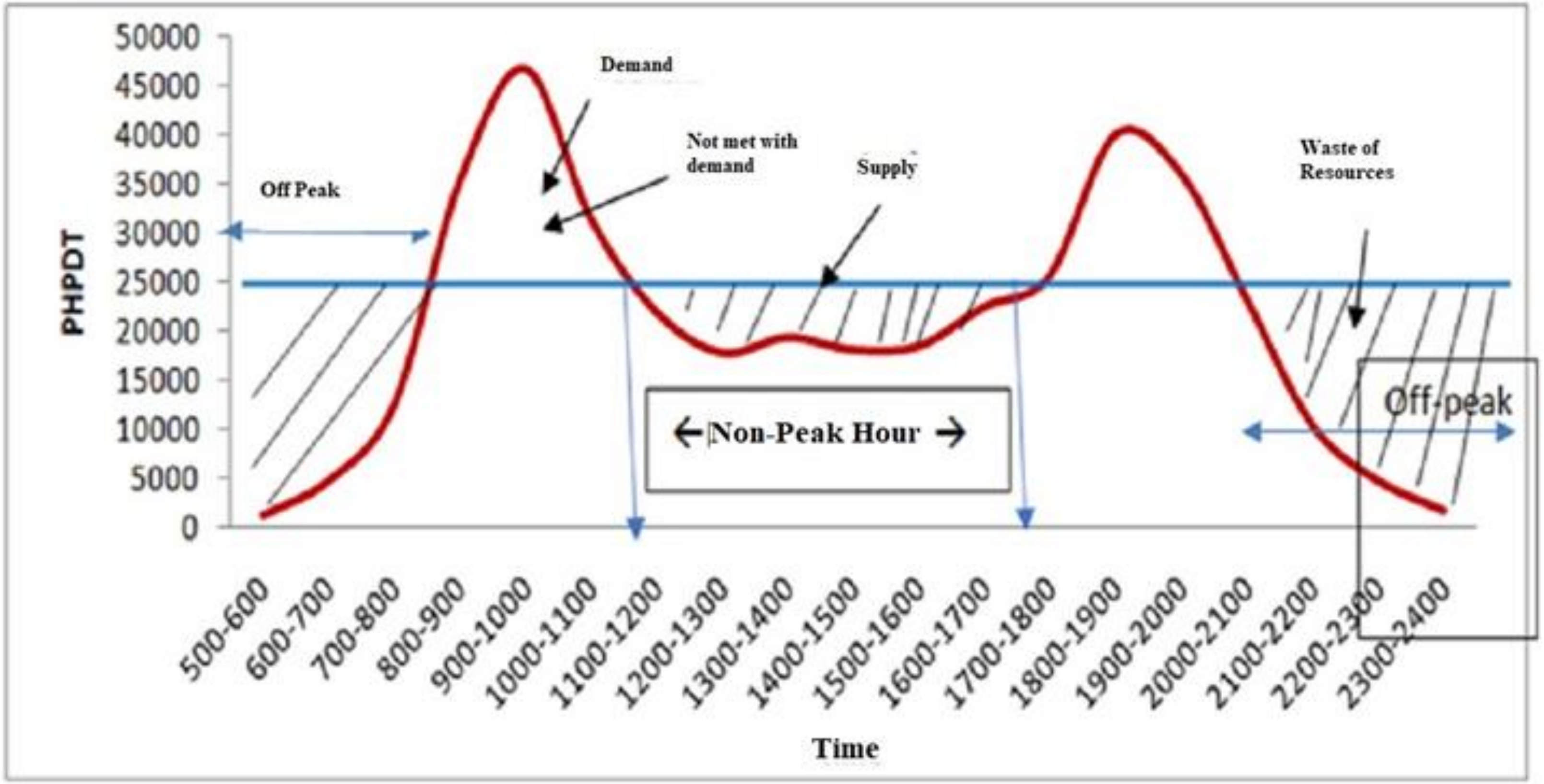
Why demand management?

- Over crowding
  - Dissatisfaction
  - Discourages modal shift from private to public

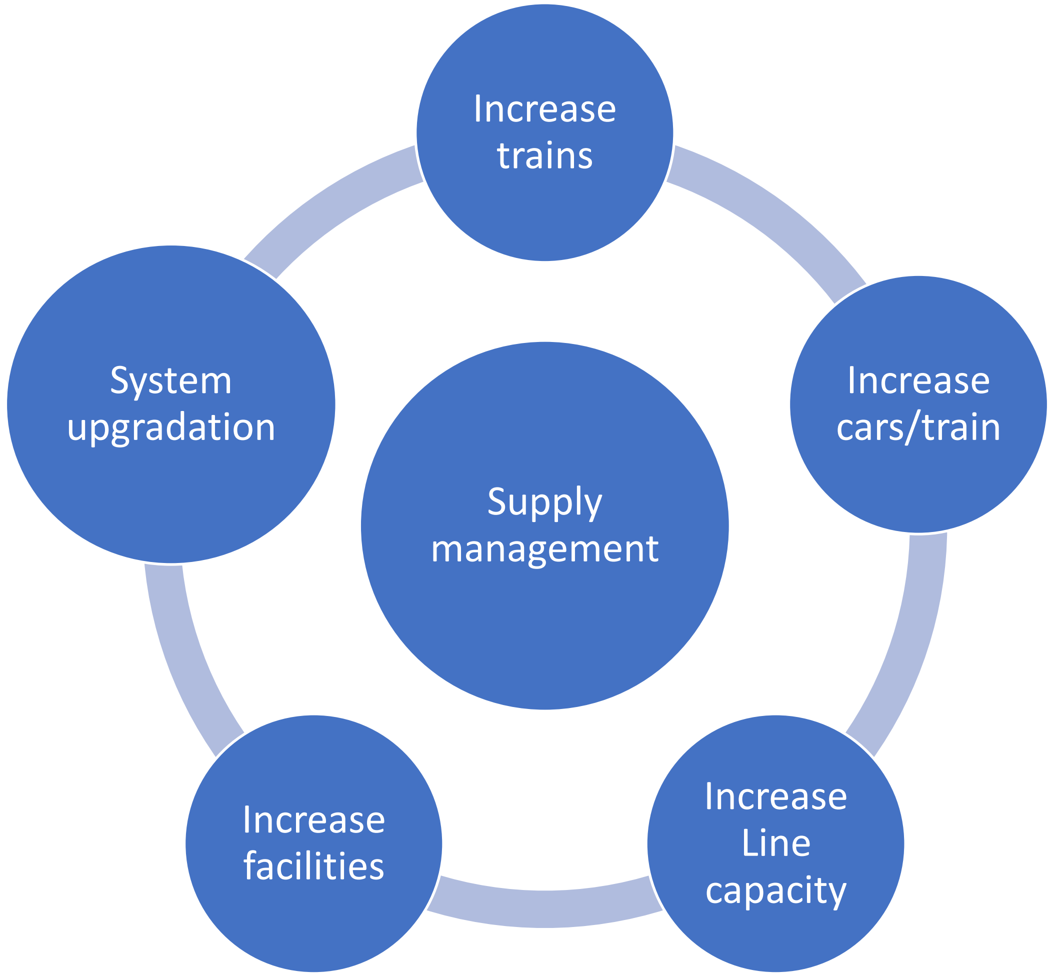
- Suboptimal utilisation of infrastructure

- Profitability

Hourly Variation of Travel demand



Supply side Measures



Supply side solution :Limitations

Infrastructure needs to be designed for peak hour demand.

Limited upto the capacity of infrastructure

Any addition beyond capacity needs improvement in track, signaling, rolling stock, manpower- huge capital investment

Suboptimal utilization of capacity created

Demand side measures- Transport Demand Management (TDM)

- Strategies and policies to reduce travel demand,
- To redistribute this demand in space and time
- Required for mitigation of overcrowding and for optimal utilization of fixed assets.

National Urban Transportation Policy, 2014

*"**Transportation Demand Management (TDM)** There is a need to control the growth in transport demand because there is a limit to the augmentation of UT infrastructure and services. TDM constitutes a set of policies that influence why, when, where, and how people travel. Commuters need to be made aware of the available sustainable alternate modes of travel. They should be made aware of the quantifiable benefits or drawbacks of opting for a specific mode in terms of travel time, convenience, comfort, price, and emission rates. TDM aims to maximise the efficiency of UT by discouraging the necessity of private vehicle use and promoting more effective, healthy, and environmentally friendly modes of transport. The Government of India would financially support to implement the TDM measures by cities"*

TDM in road sector

- Push-Pull people from Private to Public Transport
- TDM for Metro Operations is not about discouraging people to use PT

TDM for Metro Operations

- City-Level Measures
- Metro Planning
- Metro Operations

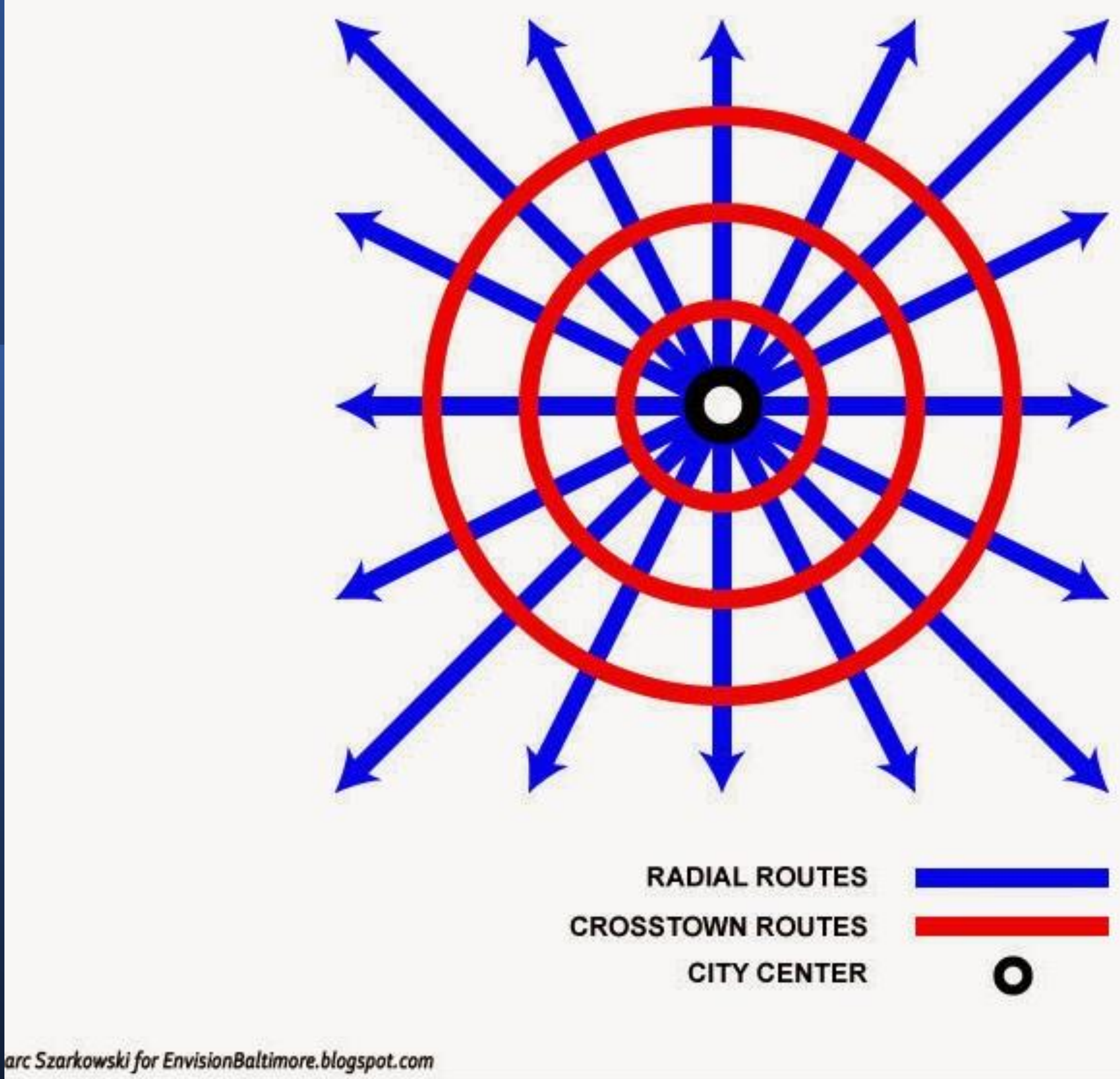
TDM – City Level measures

- Land Use Planning
- Development of a Polycentric City
- Integrated Multi-Modal Transport
- Work From Anywhere
- Promotion of e-commerce
- Staggered Working Hours
- Flexi Working Hours or Days
- Other Measures- home delivery of food, e-Learning,

TDM-Metro Planning

- Network Design
- Integrated Multi-Modal Terminals
- Convenient (Interchange) Transfer Stations

Network Design



Network Design

- Radial to circular network to
  - Offer more opportunities of transfer
  - Reduce travel distance
  - Reduce congestion at central stations
- ***Redistribution of demand across time and space***

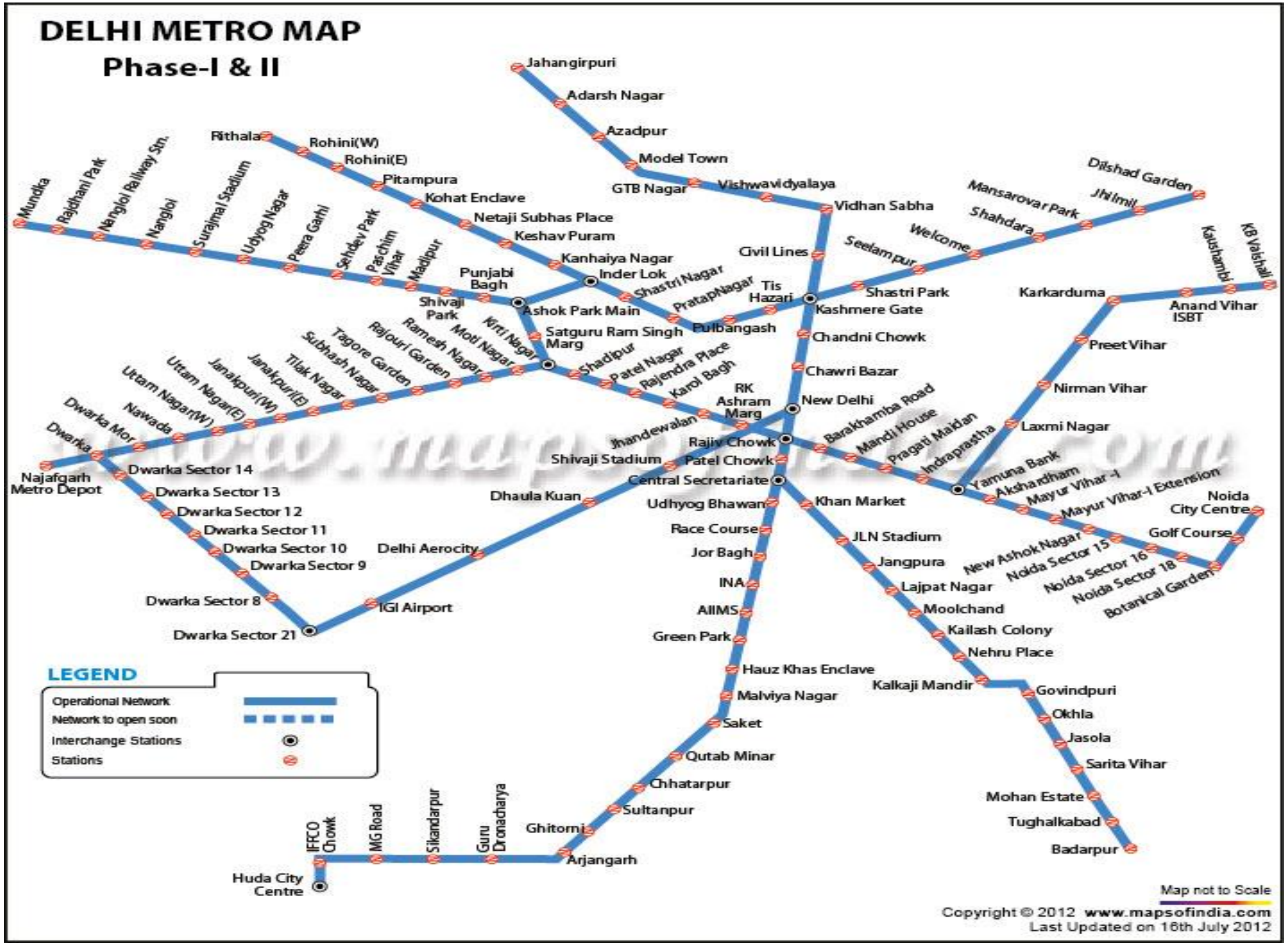
Network Design: DMRC

- Upto Phase II – Radial Network with 9 interchange points
- Phase III of DMRC is focussed on developing circular lines and creating grid network to offer more opportunities to transfer
- ***24 interchange stations by the end of Phase 3***

Results:

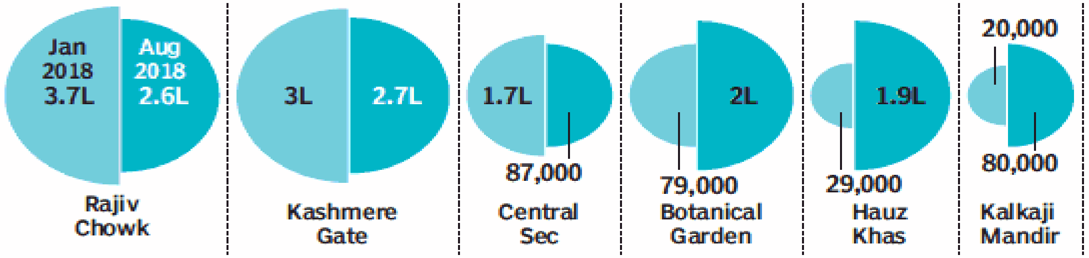
- ***Decongestion of stations***
- ***Redistribution of demand across time and space***

Delhi Metro upto Phase II- 2014



Delhi Metro upto phase III

NUMBER OF PEOPLE WHO VISIT THESE INTERCHANGE STATIONS DAILY



29 lakh Average daily ridership

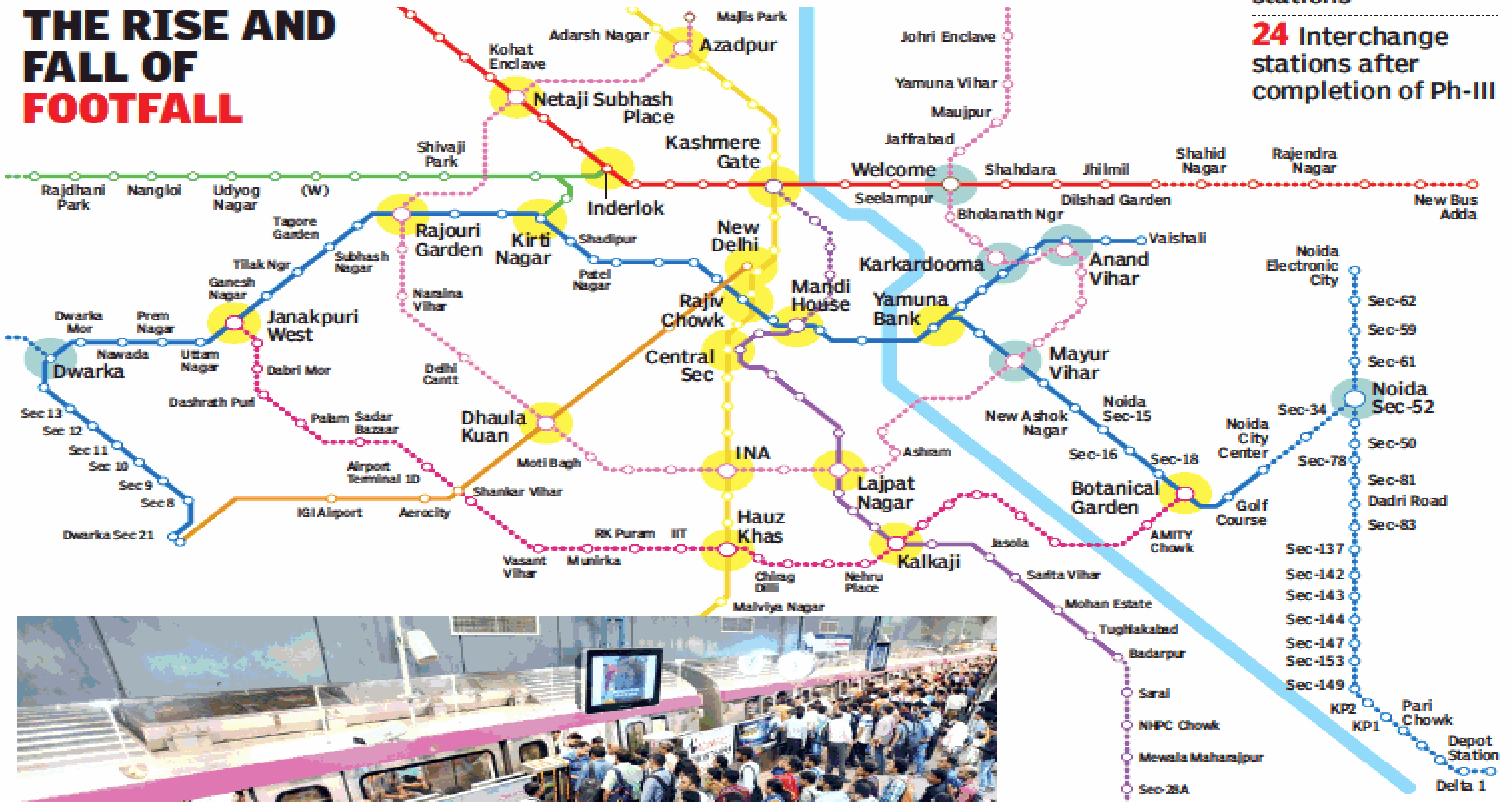
296 km Length of Delhi Metro network

3,800 Daily trips

18 Interchange stations

24 Interchange stations after completion of Ph-III

THE RISE AND FALL OF FOOTFALL



INTERCHANGE STATIONS Kashmere Gate, Rajiv Chowk, Central Secretariat, New Delhi, Azadpur, INA, Hauz Khas, Mandi House, Yamuna Bank, Botanical Garden, Sikandarpur, Inderlok, Netaji Subhash Place, Kirti Nagar, Dwarka Sector 21, Janakpuri West, Rajouri Garden, Lajpat Nagar

UPCOMING INTERCHANGE STNS Welcome, Karkardooma, Anand Vihar, Mayur Vihar-I, Dwarka, Noida Sector 52

Source: TOI 28.09.2018

Integrated Multi-Modal Terminals

- The metro stations need to be designed and developed as integrated multi-modal terminals to facilitate the seamless interchange of passengers among different modes such as metro trains, buses, NMTs, paratransit modes.

- The integrated multimodal station helps in distributing the travel demand among the most suitable mode of transport and thereby manages the demand.

Convenient (Interchange) Transfer Stations

- Convenient, hassle-free, and seamless for the optimal redistribution of demand across different lines.
- The transfer should not require entry or exit through fare control gates.
- The transfer stations should be equipped with escalators, lifts, travellators and adequate signages to minimise the time taken for transfer.

TDM-Metro Operator

- **Differential pricing: Higher fares during peak hours- lower during non peak hours**
- Parking Policies - Higher rates for peak hours to encourage non-peak travel
- Incentives for travel in a non-peak hour
- Facilities to sr. citizens & disabled, reduced fare
- Integrated timetabling to facilitate transfer between lines
- Promote non-congested routes -Reduced fares and better feeder bus connectivity

INSINC Programme, Singapore

To promote travel in non-peak hours, the Singaporean government offers Incentives for Singapore's Commuters program ("INSINC program"). The registered passengers automatically earn one point for every 1 km travelled on the train all day Monday through Friday. A weekday trip of X km earns X credits, and if the trip was initiated in the non-peak shoulder hours, it earns three times credits. The credits earned by a commuter are redeemable either at a fixed exchange rate (1000 credits = SG$1) or for prizes ranging from $1 to $100 in a fun online game.

Differential Pricing

a) Peak hour surcharge

or

b) Off peak hour discount

Or

Combination of a) and b)

Differential Fares

- Higher Fares in Peak hours
  - to level demand : ease peak hour congestion
  - to meet the higher cost of operations in peak hours

- Internationally adopted measure for TDM e.g London Underground, New York Subway, Washington

- Increase fare box revenue because of low price elasticity in peak hours
- ***Price elasticity model*** to be considered

- **Implementation strategy**
  - Automatic Fare Collection system
  - Exit time is to be considered for fare calculation

Why differential pricing-Economic rationale?

- **Manage travel demand during peak hours**

  Reflect the appropriate service costs
  - The marginal cost of providing services in peak hours is more due to the more staffing and overhead costs of train operations in rush hour loads.
  - The marginal cost of services in peak hours is around three times that in off-peak hours.
- **Enhance fare box revenue and ridership in non-peak period**
  - The peak hour commuters are generally not very sensitive to hike in fares as their travel demand is in line with their work schedule.
  - Higher fares for peak hour travel increase revenue along with transferring few commuters to non-peak hours.

Why differential pricing-Economic rationale?

- **Maintain social equity**
- The peak hour travels- mostly office goers, have higher per capita income.
- The marginal cost of train services in peak hours is more
- The differential pricing strategy helps in reducing socially regressive aspects of metro train fares which results from flat or uniform fare regimes wherein <u>non-peak passengers cross-subsidise the peak period commuters.</u>

International Experience of Differential fares

- A peak hour surcharge had a greater impact than non-peak fare discounts
- Commuters are more likely to shift their travel earlier than later in response to peak smoothing incentives
- Peak smoothing initiatives targeting the morning peak are also likely to deliver smoothing benefits in the afternoon peak.

Implementation Strategy

- Automatic Fare collection System- Time based and distance based fare collection possible with modern AFC system
- Entry or Exit or both time to be considered for application of peak hour fares?
- Graduated increase to avoid queuing at the time of start of peak hour

Time of Entry/Exit for peak hour

Issue: whether the time of entry or the time of exit should be reckoned for collecting peak or non-peak hour fares.

If morning peak is 0800-1200 hours-

- Who are non-peak hour travelers? those entering before 0800 hours or those exiting before 0800 hours?
- Similarly, what about those who enter the metro network at 1130 hours and exit at 1230 hours?

A) If entry time is the deciding factor, those who enter at say 0745 hours and exit at 0845 hours will be paying non-peak hour fares although they travel predominantly in peak hours. *Heavy crowding just before 0800 hrs.*

B) If exit time is the deciding factor, a rider entering the system during peak hours (say 1130 hours) and exiting after 1200 hours, in non -peak hours, will be paying non-peak hour fares. *Commuters may wait for 1200 hrs before exiting.*

C) Another approach may be considering entry and exit time both for deciding whether a rider has travelled in peak hours. So, if a rider has travelled even a small fraction of time in peak hours, he will have to pay peak hour fares.

Practice followed in some international metros

Metro System	Peak Hours	Deciding factor for peak hour fares
DMRC	0800-1200 1700-2100	Entry time
London Underground	0630-0930 1600-1900	Entry and Exit time
Singapore Metro	Before 0745	Entry
Washington Metro	0500-0930 1500-1900	Entry

Factors critical to success of differential fare strategy

- Greater than 25% fare differentiation is required
- Allow enough time for changes to take effect: trip retiming will require passengers to make lifestyle changes, so will only become apparent in the medium-to-long term
- Service differentiation is key: Peak fare differentials to combined with improved services during the peak;
- Make changing time of travel easy and convenient for commuters: Infrastructure and ticketing arrangements

Delhi Metro model

Promote use of smart cards

- An additional 20% discount is offered to the passengers using **Smart Card** who enter the metro system during off peak/Non-peak hours based on the following time zones:
  - Start of revenue services to 08:00 AM.
  - From 12.00 Noon to 05.00 PM.
  - From 09:00 PM to closing of revenue service

The above discount is applicable from Monday to Saturday.
Further special discount is offered on Sundays and National Holidays to attract more ridership on these days.

PUBLIC NOTICE

As part of the two phase revision of Metro fares recommended by the 4th Fare Fixation Committee, fares under Phase-II of Fare revision are as given below:

Revised Fares (Monday to Saturday)

Distance zones (KMs.)	Old fare with token as on 9th October 2017	w.e.f 10th October 2017 with token (₹)	w.e.f 10th October 2017 with Smart Card during peak hours (₹)	w.e.f 10th October 2017 with Smart Card during non-peak hours (₹)
0-2	10	10	9	8
2-5	15	20	18	16
5-12	20	30	27	24
12-21	30	40	36	32
21-32	40	50	45	40
>32	50	60	54	48

Revised Fares on Sundays and National Holidays (-26th Jan, 15th Aug & 2nd Oct.)

Distance zones (KMs.)	Old fare with token as on 9th October 2017	w.e.f 10th October 2017 with token (₹)	w.e.f 10th October 2017 with Smart Card (₹)
0-2	10	10	9
2-5	10	10	9
5-12	10	20	18
12-21	20	30	27
21-32	30	40	36
>32	40	50	45

24 X 7 HELP LINE – 155370

For further details, please visit DMRC website **www.delhimetrorail.com**

Enjoy the Benefits of Off-Peak Hours

20% OFF

20% discount for Smart Card passengers entering Metro System during off peak hours*

Window of almost 11 hours provided as non-peak hours:

	From	Till
Off-Peak Hours	Start of revenue services	Before 8:00 AM
	12:00 Noon	Before 5:00 PM
	9:00 PM	Close of revenue services

*Cumulative i.e. 10% discount on Smart Card + 10% discount during off-peak hours

Safe and convenient commute for women

- Women only coach in every train.
- Reserved seats for women in every coach.
- CCTV surveillance at stations, platforms and in train coaches.
- Female CISF staff have been deployed at stations for frisking of lady passengers.

Senior citizens

- Reserved seats, lifts and escalators, ramps

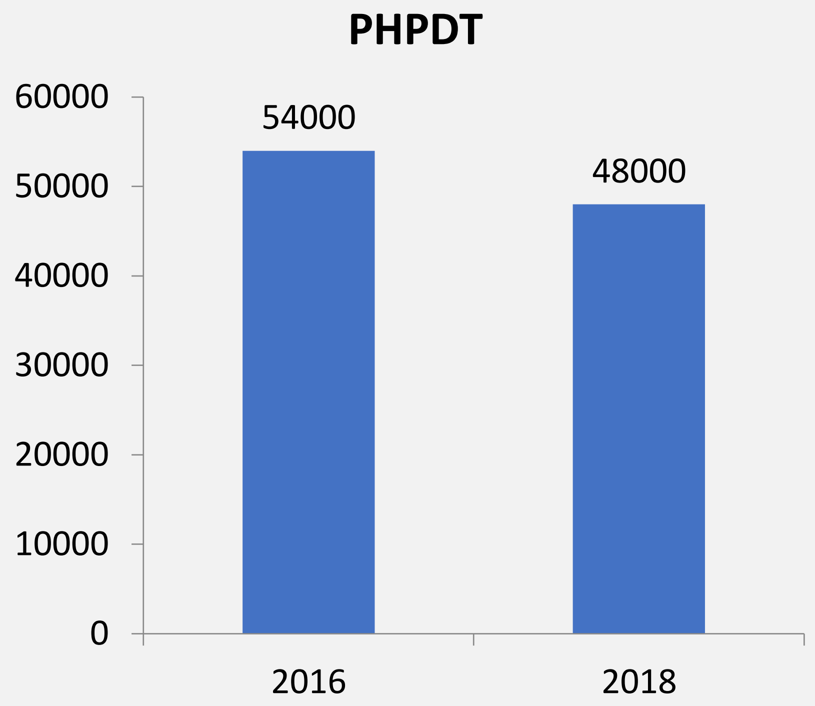
DELHI METRO
मेरा मेट्रो

DELHI METRO RAIL CORPORATION

Results: Differential fares

Decongestion: Peak hour demand has come down

Demand Leveling- Difference between peak and non peak demand has come down



Service augmentation in off peak hours

- Improved frequency of trains
- Adequate ticketing facilities
- Availability of parking
- All station facilities such as escalators/lifts shall be functional

Capacity augmentation in non-peak hours

- Capacity augmentation in Non peak hours along with differential fares is effective in transferring demand from peak to non peak hours.
- DMRC has informed that they have increased frequency of trains in non peak hours

No.	Year	Line-1		Line-2		Line-3/4		Line-5		Line-6	
		Peak	Off-Peak	Peak	Off-Peak	Peak	Off-Peak	Peak	Off-Peak	Peak	Off-Peak
1	Mar-2015	3'15"	5'00"	2'50"	3'24"	2'36"	2'52"	4'38"	5'24"	3'09"	6'00"
2	Mar-2017	3'15"	3'53"	2'40"	2'45"	2'30"	2'42"	3'38"	4'38"	3'20"	4'00"

Promoting non- congested routes

- In case of parallel/alternative routes
  - Identify congested routes
  - Promote non congested routes
    - Fare concession
    - Better services- increase frequency
    - Marketing/advertising
    - Availability of tickets and other facilities
    - Smooth interchange
    - Complementary time tabling

Promoting non- congested routes

Congested route	Alternate routes	Strategy
Dwarka 21-Rajiv Chowk (Blue line)	Dwarka 21- New Delhi (Airport Line)	Rationalization of fares of Airport line, Convenient interchange at Dwarka 21
Faridabad-Rajiv chowk via CTST-RCK	Faridabad-Rajiv Chowk via CTST-MDHS	More services on violet line Convenient interchange at Mandi House (MDHS)
Mundaka –Rajiv Chowk via Inderlok	Mundaka-Rajiv Chowk via Kirtinagar	More services to Kirtinagar Convenient interchange at kirtinagar Originating services on redline

Results

- DMRC is promoting non congested routes Airport Express Line as an alternative to blue line through media campaigns, interaction with passengers, announcements, etc: ***Around 5% riders of Blue line have been shifted to Airport Line.***
- Mandi House-CTST route is being promoted as an alternative to Rajiv Chowk-CTST- ***Decongested Rajiv Chowk***

Rationalisation of last mile connectivity- feeder buses

- The feeder bus may be provided at non-congested stations to shift traffic

- Rationalized feeder bus routes to connect non congested stations with feeder buses

Delhi govt fixes routes of Metro feeder buses to improve last-mile connectivity

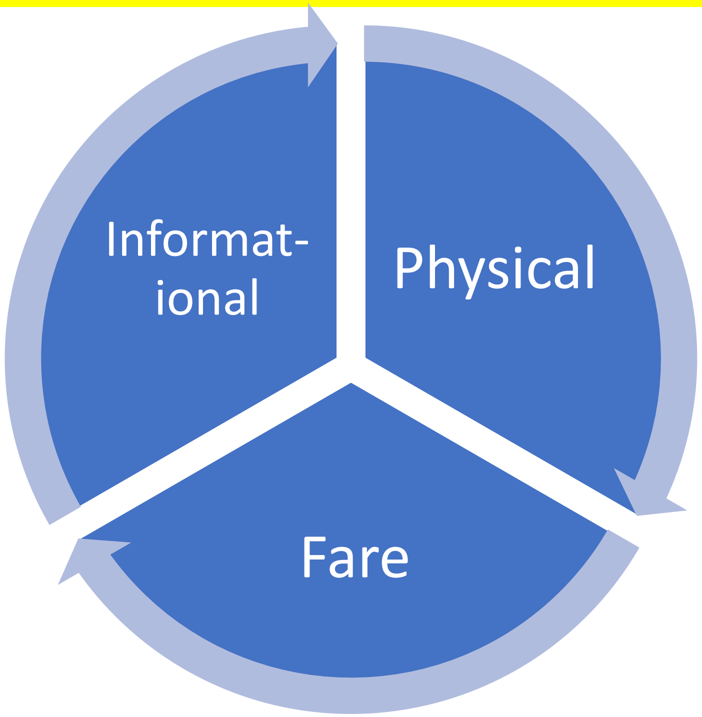
Buses that bring Delhi Metro stations closer for residents will run on new and improved routes. The State Transport Authority aims to rationalise the routes so that they help remove congestion in the Capital.

DELHI Updated: Jan 18, 2017 14:20 IST

Sweta Goswami
Hindustan Times

Integration with other modes of transport

- To redistribute demand across multiple modes of transport
- Transport system in a city is sum of all modes of transport- Complementary not competitive



Integration with Other Modes

- Fare Integration
- Common mobility Card

- Physical Integration
- Multi Modal Integration-UTTIPEC

- Information Integration
- Information about other modes available at metro stations

- Supply side measures are limited by capacity constraints
- Demand Management tools
  - Differential Fares
  - Network Design
  - Capacity augmentation in non peak hours
  - Feeder bus rationalisation
  - Integration with other modes
  - Promote non-congested routes

THANK YOU