Satish Kumar

Director - (Electrical)

Delhi Metro Rail Corporation

Mr. Satish Kumar, Director (Elect.), Delhi Metro Rail Corporation Ltd (DMRC) is an officer of Indian Railway Service of Electrical Engineers of 1967 Batch.

Since, 1998 when he joined Delhi Metro, he was the Director in-charge of Rolling Stock, Electrical & Mechanical Services, Signal and Telecommunication, Fare Collection. He has been involved in taking various key decisions in the selection of basic parameters, technology and implementation of the project to a time bound programme, the first Phase of which has been executed on a world-class standard to schedule. He was also Director in-charge of Operation & Maintenance upto December' 05.

Before joining DMRC, he was Officer on Special Duty/Adviser(RE) in Indian Railway Board and had held various other posts on Indian Railways during his long career with Railways including Executive Director,(Rolling Stork) in 1988-91, when he was associated with three phase technology transfer in electric locos and EMUs.

He had also worked for Ring Railway Electrification project before the Asiad in 1981-82.

For over five years, as Joint Secretary (Ordnance Factories) in the Ministry of Defense, he was a member of the Board, controlling a group of 39 production units & was associated with major projects and technologies absorption from DRDO and abroad.

DMRC

Metro Coaches (Design & Maintenance) MRTS, Delhi

by

Satish Kumar, Director (Elect.)

February 13, 2008

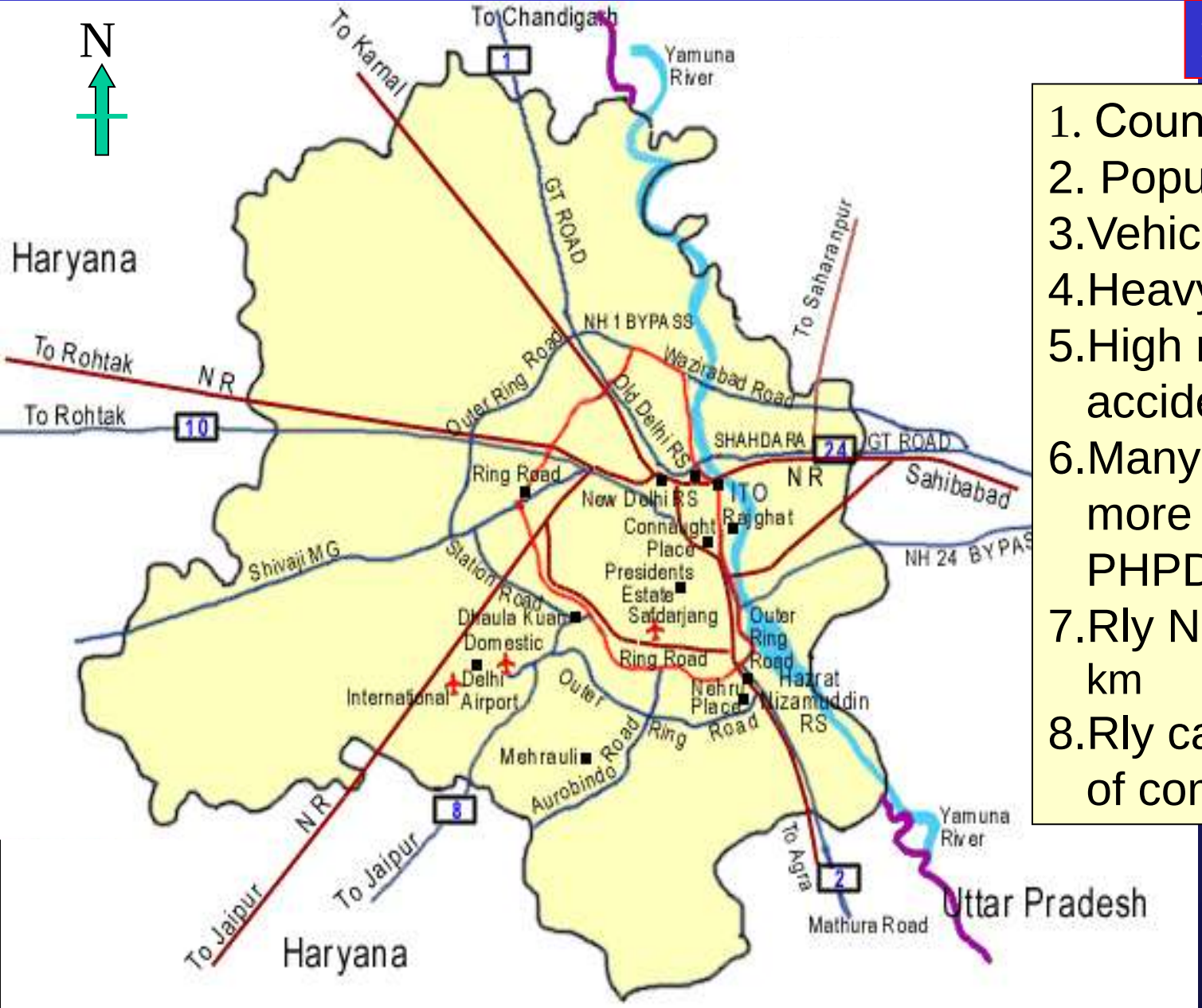
Railway Staff College, Vadodara

International Course for BIMSTEC

CONTENTS

1. Introduction to DMRC Project
2. Rolling Stock for MRTS, Delhi
   - Considerations in choice of Technologies
   - Design Philosophy and Requirements
   - Important Salient Features
   - Reliability & Energy Efficiency Features
   - Passenger Safety & Comfort Features
3. Maintenance – Need Based on Feed Back
4. Phase II – Rolling Stock – further improvements
5. Conclusions

DELHI



1. Country's capital.
2. Population –14 Mn
3. Vehicles › 5 Mn
4. Heavy pollution
5. High rate of road accidents
6. Many corridors carry more than 20000 PHPDT
7. Rly Network – 144 km
8. Rly carries only 2% of commuters.

Delhi is the 2nd City in the Country to have a Metro System, 1st being Kolkata

TRANSPORTATION IN DELHI

- 98% PUBLIC TRANSPORT TRIPS BY ROAD:
  - HEAVY CONGESTION ON DELHI ROADS EVEN THOUGH AREA UNDER ROADS IS 21% OF CITY AREA
- POPULATION OF MOTOR VEHICLES IS 5 MILLION
  - THIS IS MORE THAN THE COMBINED MOTOR VEHICLES OF THE OTHER THREE LARGEST CITIES IN INDIA, NAMELY, MUMBAI, CHENNAI AND KOLKATA
- VEHICLE POPULATION INCREASING BY 7% PER YEAR.
- WITH SUCH CROWDED ROADS DELHI IS ONE OF THE MOST POLLUTED CITIES IN THE WORLD.
- THE ACCIDENT RATE ON DELHI ROADS IS ALSO VERY HIGH

Road Accidents In Delhi

- Average no. of persons killed/day - 5
- Average no. of persons injured per day - 13

Buses contribute majority of the accidents.

FEASIBILITY STUDIES FOR METRO SYSTEMS

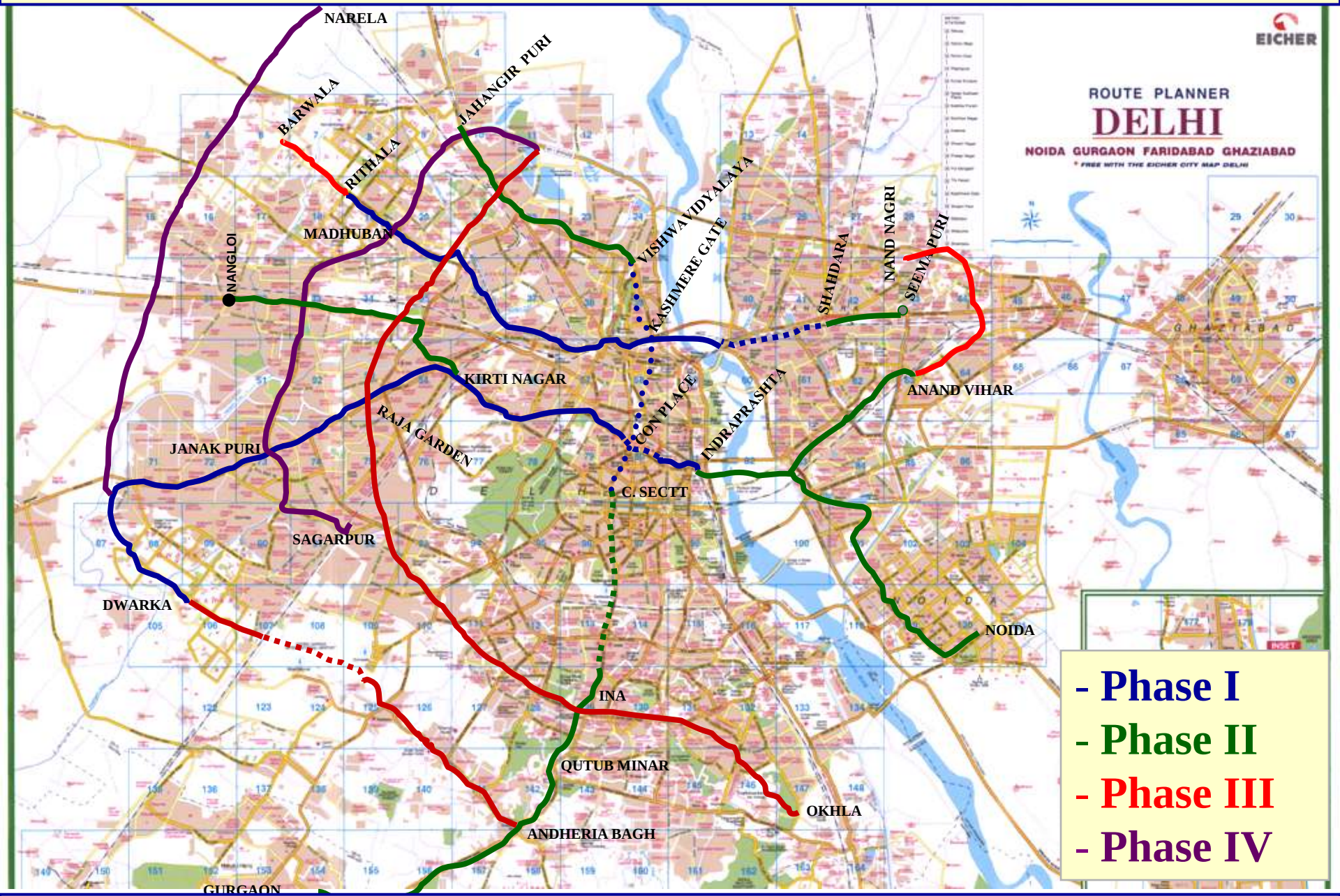
- SINCE 1950, 34 STUDIES WERE CONDUCTED TO FIND AN OPTIMAL SOLUTION TO THE TRANSPORTATION PROBLEMS OF DELHI.
- ALTHOUGH MANY PROPOSALS WERE DEVELOPED TO PROVIDE A METRO SYSTEM IN THE CITY, NO PROJECT COULD BE TAKEN UP FOR WANT OF FUNDS.
- IN 1989 A COMPREHENSIVE STUDY WAS CONDUCTED WHICH IDENTIFIED EIGHT LINES 200 KM TO BE TAKEN UP TO MEET DELHI'S NEEDS.
- THE STUDY RECOMMENDED A METRO SYSTEM CAPABLE OF CARRYING 60,000 TO 80,000 COMMUTERS PER HOUR IN EACH DIRECTION (PHPDT)

CONTD……

FEASIBILITY STUDIES FOR METRO SYSTEMS

- AS PER REVISED MASTER PLAN FOR METRO NETWORK THE CITY WARRANT A TOTAL NETWORK OF 381 KM IN FOUR PHASES:
- PHASE-I KM 65.1 COMPLETED
- PHASE-II KM 125.04 UNDER CONS-TRUCTION
- PHASE-III KM 114.67 BLUEPRINTED
- PHASE-IV KM 76.30 BLUEPRINTED

MASTER PLAN



-- At Grade … U/G - Elevated

DELHI METRO RAIL CORPN (DMRC)

- TO IMPLEMENT DELHI MRTS PROJECT A SPECIAL PURPOSE VEHICLE IN THE NAME OF DELHI METRO RAIL CORPORATION LTD.WAS INCORPORATED IN MAY 1995.

- GOVT. OF INDIA AND GNCTD AGREED TO BUILD THIS PROJECT AS A JOINT VENTURE PROJECT WITH 50 : 50 EQUITY PARTICIPATION.

- THE CABINET GAVE INVESTMENT APPROVAL TO THIS PROJECT IN 1996 AND ACTUAL WORK STARTED IN 1998

- DMRC HAS THE RESPONSIBILITY FOR CONSTRUCTION AND OPERATION OF DELHI METRO

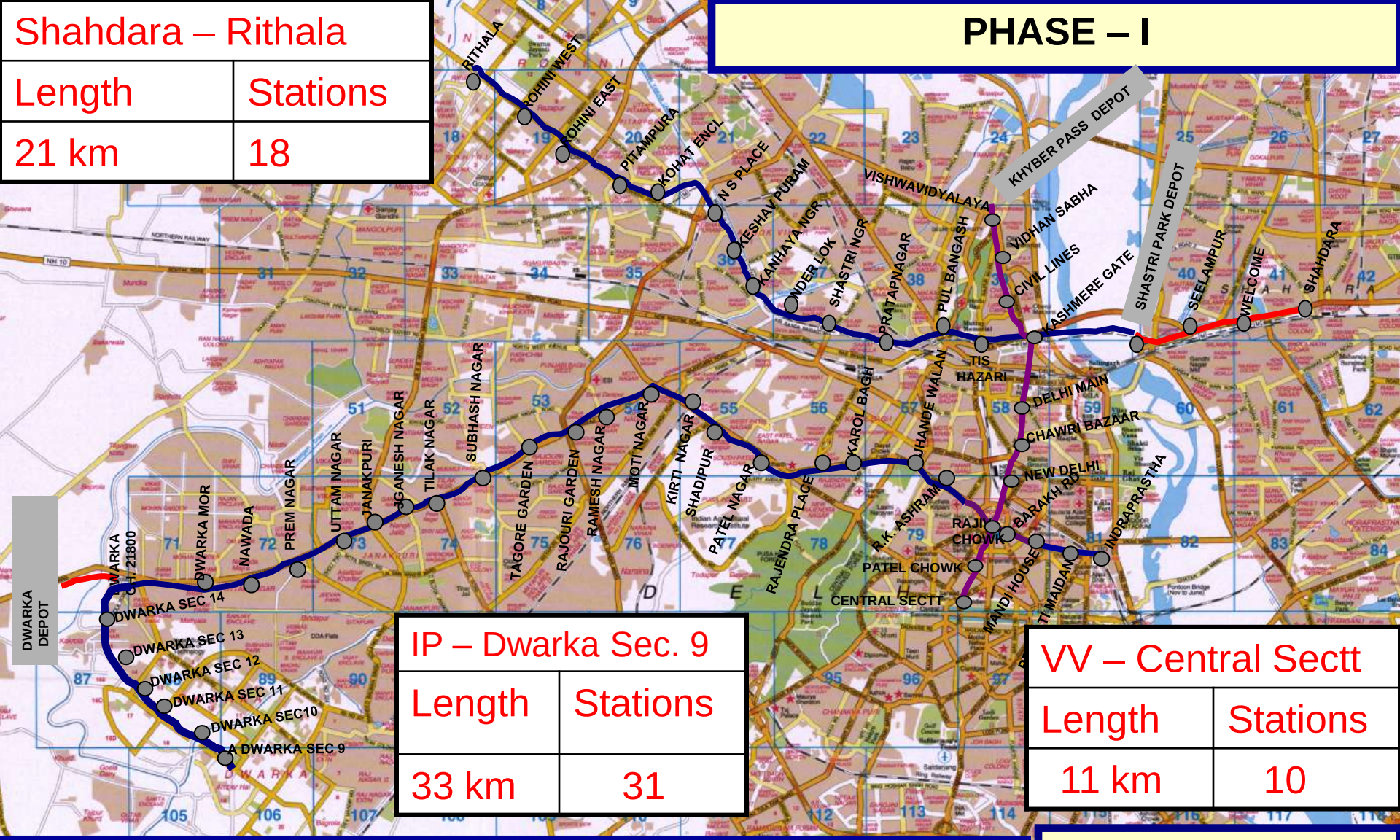
SET UP OF DMRC

- OVERALL MANAGEMENT TO THE BOARD OF DIRECTORS HAVING EQUAL NUMBER OF NOMINEE DIRECTORS FROM BOTH THE GOVTS ALONG WITH FUNCTIONAL DIRECTORS

- TO REMOVE BOTTLENECKS, AN “EMPOWERED COMMITTEE” HAVING REPRESENTATION FROM IMPORTANT MINISTERIES

- FOR MAJOR POLICY DECISIONS, COMMITTEE OF SENIOR CABINET MINISTERS (GOM)

PHASE – I



Shahdara – Rithala	
Length	Stations
21 km	18

IP – Dwarka Sec. 9	
Length	Stations
33 km	31

VV – Central Sectt	
Length	Stations
11 km	10

- Three lines
- Total length – 65 km

(Elevated-47.1 km, U/G-14.5 km, At Grade-3.5 km)

- Total No. of Stations – 59

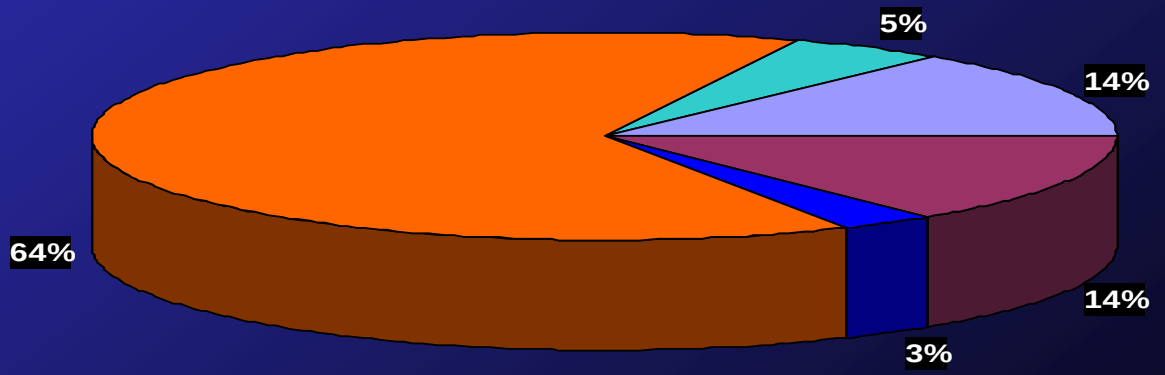
At Grade
Elevated
Underground

DELHI MRTS
COST & FUNDING PLAN

ESTIMATED COMPLETION COST OF THE PROJECT BY SEPT, 2005: RS. 10,571 CR i.e. US$ 2.1 Bn.

FUNDING PLAN

- GOI EQUITY 14%
- GNCTD EQUITY 14%
- PROPERTY DEVELOPMENT 3%
- JBIC LOAN 64%
- INTEREST FREE SUBORDINATE DEBT TOWARDS LAND COST 5%



SALIENT FEATURES OF METRO

Inter station distance	1 to 1.1 km
Schedule speed	32 to 35 kmph
Frequency of train Design underground elevated	3.0 min. 1.5 min 2.0 min
PHPDT Future PHPDT	60,000 80,000

System Parameters

- **Gauge**
  - Broad Gauge (1676 mm.)
- **Rolling Stock:**
  - 3.2 m wide Stainless Steel, Air Conditioned for all the corridors.
  - 8 car train formation (Initially 4 car)
  - Axle Load – 17 MT
- **Traction:**
  - 25 KV overhead.
- **Signalling:**
  - Cab signalling with ATP.
  - ATO to be introduced later.
- **Train Frequency:**
  - 3 minutes initially
  - To be reduced to 120 sec. finally

FEATURES OF PHASE–I

- PHASE-I COMPLETED 2 YRS 9 MONTHS AHEAD OF SCHEDULE.
- WORK COMPLETED WITHIN ESTIMATED COMPLETION COST
- THE UNIT COST OF CONSTRUCTION IS ONE OF THE LOWEST ANYWHERE IN THE WORLD.
- USERS FRIENDLY FOR PHYSICALLY CHALLENGED
- METRO IS OF WORLD–CLASS STANDARD
- AC COACHES, ATP, ATO, AFC
- SPEED: MAX 80 KM / H - AVERAGE 32 KM/H

OPERATION HIGHLIGHTS

- ABOUT 1260 TRAIN TRIPS A DAY – WITH 70 TRAIN SETS
- EACH TRAIN CONSISTS OF 4 COACHES
- AVERAGE RIDERSHIP – 650,000 PER DAY
- FREQUENCY DURING PEAK HOURS – 4 MINUTES.
- TRAINS OPERATE FROM 6 AM TO 11 PM
- PUNCTUALITY MEASURED WITH A LEAST COUNT OF 60 SECONDS
- FARE : FROM RS. 6/- TO RS. 22/- *LOWEST IN THE WORLD EXCEPT KOLKATA*
- NO OPERATIONAL SUBSIDY FROM GOVERNMENT
- REGULAR IN SERVICING AND PAYING BACK LOANS

ROLLING STOCK

- **It is the Main Stay of MRTS to carry high volumes of passengers**
  - **Regularly**
  - **Punctually**
  - **Safely**
  - **Efficiently**
  - **Reliably**
  - **Environment friendly**

CONSIDERATIONS IN CHOICE OF TECHNOLOGIES

- **Life Cycle Cost**
  - Procurement Cost
  - Energy Consumption
  - Maintenance Cost Inventory
  - Reduced Manpower
  - Reduced Space
- **High Reliability & Availability**
- **Better Comfort**
- **Environment of Delhi**
- **Other Special Conditions based on experience of Railway System in India**

Basic Design Philosophy & Requirements

The design philosophy should meet the following Criteria:

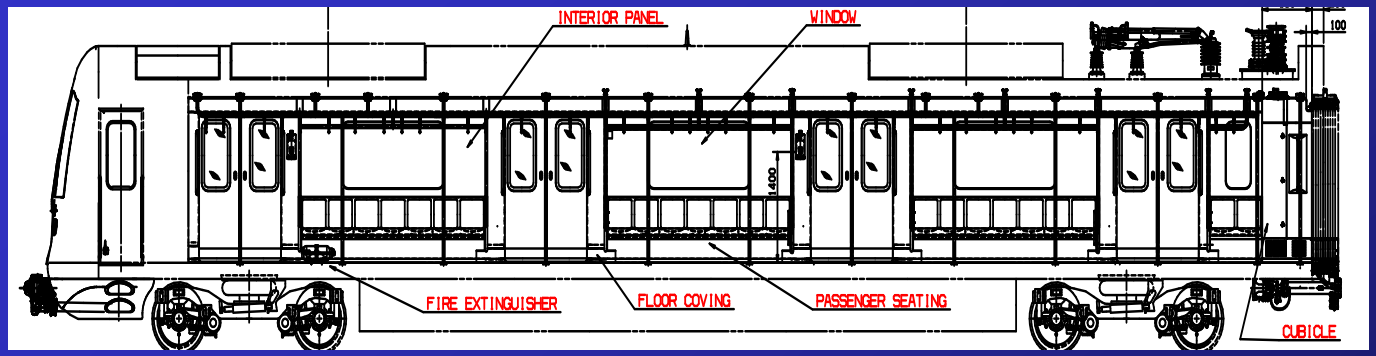
1. Application of state-of-the-art technology
2. Lightweight integral car body
3. Service proven design
4. Design life 30 years
5. Crashworthiness
6. Low life cycle cost
7. Low maintenance and overhaul cost
8. Use of interchangeable, modular components
9. Extensive and prominent labeling of parts and wires
10. Use of unique serial numbers for traceability of components

11. High reliability
12. Low Energy consumption
13. System safety
14. Adequate redundancy in system
15. Smoke detection and protection
16. Use of fire retardant materials
17. High passenger comfort including low noise level
18. Environmentally friendly
19. Adherence to operational performance requirements
20. Safe passenger evacuation in emergency

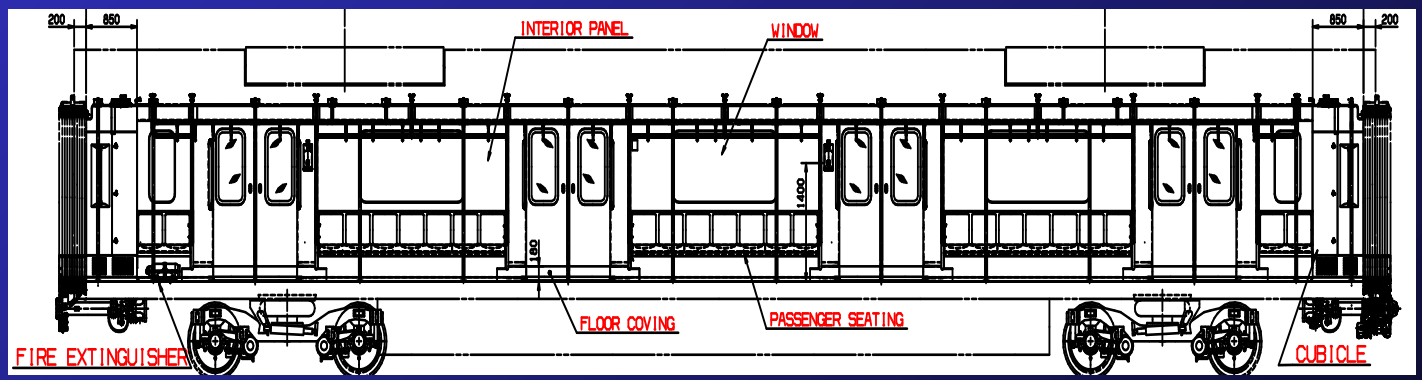
Important Salient Features

- 3.2 m wide, 22m long coaches
- Acceleration : 0.8 m/sec^2
- Deceleration : 1.0 m/ sec^2
- Average Emergency Braking Rate : 1.3 m/ sec^2
- Jerk Rate : 0.7 m/ sec^3
- Max. Speed : 80 kmph
- Schedule Speed : 32-35 kmph
- Stainless steel, light weight

DRIVING TRAILER CAR



MOTOR CAR



- Improved Ride Index
- Reduced external and internal noise
- Effective Air Conditioners
- Automatic couplers
- Passenger Emergency Alarm
- Automatic Passenger Information system
- Brake compensation system
- Maximisation of Passenger carrying capacity

- 3 phase drive propulsion system with VVVF drive
- Regenerative Braking
- Propulsion & Braking suitable for ATP, ATO
- Automatic Door Closing & Opening
- Emergency communication between passengers & driver, OCC
- Automatic announcement system
- Dedicated Space for Wheel chair

MAXIMISATION OF CARRYING CAPACITY

Carrying capacity is maximised by:

- All equipments under frame mounted
- Provision of longitudinal seating arrangement
- Provision of wide stand-back areas
- Provision of wide inter car gangway for uniform passenger distribution

Carrying capacity of 8 car train

Modern	3.2 m wide	3000
Conventional	3.66 m wide	2500

Fig. 2


ACE
2 10:21

G. T. Road Fly over - Integral Bridge

Bored Tunnel

EFFICIENCY & RELIABILITY FEATURES

- Coach shell
- Propulsion System
- Brake System
- Bogie
- Auxiliary Inverter
- Improved System Design
- Low Loss Materials

Coach Shell

Stainless Steel Car body

Light Weight – integrally structured

Aerodynamic profile

No Corrossion repairs

Smooth exterior finish

No painting required

PROPULSION SYSTEM

Converter Inverter

IGBT based PWM Control

VVVF Technology, Natural cooled

Efficiency - 99%

Maintenance free

High Power to Weight Ratio:

- DMRC Stock (IGBT) : 0.56
- GTO Based : 0.3

PROPULSION SYSTEM

Traction Motor

Three phase Asynchronous Motor

Efficiency - 93%

Self Ventilated

High Power to Weight Ratio:

- **DMRC Stock (AC) : 0.29**
- **DC Motor : 0.09**

PROPULSION SYSTEM

Traction Transformer

No oil filtration in service life

Low fire load

Maintenance free

High Power to Weight Ratio:

- **DMRC Stock : 0.4**
- **Conventional EMUs : 0.3**

BRAKE SYSTEM

EP & Dynamic Brake Blending

Regenerative Braking:

Available over almost entire speed Range

30 to 35% of total consumption

Reduced brake blocks wear

Reduced heat dissipation

Reduced load on VAC

Increased wheel life

Precise Wheel Slip/Slide Control

Bogies with better ride Index

Salient Features:

Light Weight, fabricated, bolsterless

Suspension

- **Primary : Steel & Rubber**
- **Secondary : Pneumatic**
- **Weight**
  - **DMRC : 6 Tonne**
  - **Conventional : 7 Tonne**

Auxiliary Inverter

Salient features:

IGBT based PWM Control

Natural Cooled

Efficiency - 95%

Maintenance free

High Power to Weight Ratio:

- DMRC Stock (IGBT) : 0.08
- MG Set : 0.02

Energy Efficient features:- System Design

Staggered start of auxiliary load
State-of-the-art computer based control and diagnostics
Regenerative Braking
Load dependent Traction/Braking force

Energy efficient mode in ATO

Online monitoring of Energy Consumption

Static drive for Compressor Motor

Energy Efficient features:- Light/Low loss materials

- Low loss cables
- Double pane saloon window glasses
- Light weight (Al) door panels
- Light weight interior panels
- Extensive use of FRP panels
- Light weight Gangways

Saving in energy consumption compared to conventional EMUs

6% to 8% reduction due to less tare weight and improved efficiency of equipments

30% to 35% reduction due to regeneration

Total 35% to 40% reduction in energy consumption

Passenger Comfort & Safety Features:

1. Bogies with Secondary Suspension
2. Jerk Control
3. Air Conditioning, Heating
4. Automatic Doors
5. Public Address System, Emergency Communication
6. Uniform Floor height
7. Wheel Chair
8. Wide Gang Way
9. Emergency Door

Air-conditioning System

- Two roof mounted package type – automatic control.
- Programmable Logic Controllers (PLC) used to perform control and diagnostic functions.
- Proportional Integral Derivative (PID) for fast/better control and communication.
- Following parameters being monitored by TIMS:
    - The saloon ac faults
    - Actual & set Saloon temperature
    - Status of ac mode

Doors

- Four pairs of externally hung, sliding, bi-parting electrically driven doors per car side
- Following parameters monitored on TIMS
  - Obstruction detection feature
  - The position of doors
  - Door Faults
  - Opening and closing time
  - Number of door operation cycles

On board Passenger Information & Public Address System

- Audio & Visual information to passengers.
- This requires 28 computers per train
- System adjusts audio amplitude based on background noises.
- Station arrivals, door closure / opening made automatically.

Train Integrated Management System (TIMS – based on IT)

- Monitoring of faults & Status of subsystems
- Recording of Faults & Energy consumption
- Log of last eight hours of Speed
- Log of last eight hours of status of Cut out switches, Mode selector, Master Controller

Train Integrated Management System

All the vital subsystems being monitored byTIMS:

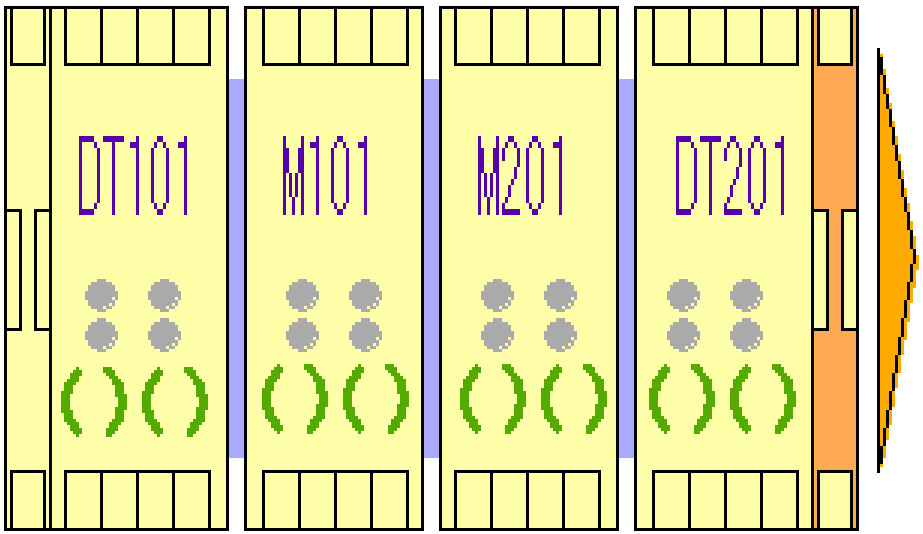
- Traction System
- Auxiliary Power Supply System
- Brake System
- Door System
- AC System
- PA & PIS System

DOORS

HELP 12.04.01 07:42:23

FAULT

ID:12345 | RAKE ID:123 | CUR: TZI | NEX:PBGH | 7654321km



ADCR : ENERGIZED

DPR : DE-ENERGIZED

NORMAL – DPLCOS – NORMAL

DOORS | BRAKES | POWER | AUX. | AIR CON. | HISTORY | DEPAR TURE | MAINT. MENU | MAIN

Fig. 1

Passenger Comforts

Wide-Opening Gangway

- ***Accommodation of standee***
- ***Wide gangway between coaches***
- ***Provision of Comfort at all location***
- ***Permission of Easy Passage***


आपातकालीन द्वार कैसे खोलें
How to open the Emergency Exit
1
Push handle across
2
3
Exit
Emergency Exit
the operator's cab
2 10:22

Reliability and Availability

Specified MDBF 40,000 km

Delay of 3 Mins or more is considered failure

1. **<u>Punctuality achieved by DMRC:</u>**

More than 99%

Operational Strategies

Optimized Headway:

Peak hour	-	4 mins
Off Peak hours	-	7 to 10 Min

Reduced idle running of trains

Rakes withdrawn during off peak period

Stabling facilities provided at terminal stations

Maintenance Schedules:

Description	Schedule for DMRC Stock	Schedule for IR car
Light Inspection	3 day	Daily
Heavy Inspection	1 year	4 months
Intermediate overhaul	3.5 to 4 years	Yearly
Heavy overhaul	7 to 8 years	2 yearly
Corrosion repair	Not expected	5-6 yearly

DEPOTS

Three Maintenance Depots

One for each line

Combined capacity 154 trains

Existing 70 Trains

Special Facilities

- Automatic Wash Plant
- Crane over 25 KV ac in Inspection shed
- Sunken jacks in Workshop

Further Improvements for Phase-II

Wheel mounted disc brakes

Reduced Noise levels

Improved Air conditioning

Passenger Surveillance System

Trains under procurement

B.G - 85 (Each of 4 coaches)

S.G. - 40 (Each of 4 coaches)

Conclusions

Technology choice and laying basic design and performance requirements has resulted in energy efficient, rolling stock as well as

- **More passenger comfort**
- **Better safety features**
- **High availability and reliability**
- **Lower maintenance requirements**

THANK YOU

DMRC LTD.

N.B.C.C. Place
Bhishma Pitamah Marg
Pragati Vihar
New Delhi - 110 003.

PRINCIPLE OF ATP SYSTEM

The On Board Computes the speed distance profile taking into account the safety margin