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0. EXECUTIVE SUMMARY

0.1. Background

National Capital Region (NCR) is a unique example for inter-state regional development planning for a region with Nation Capital at its core. It is one of the largest National Capital Region of the World and constitutes about 1.60% of the country's land area. NCR is the home of 371 lakhs people living in 108 towns of which 17 are class I cities and more than 7500 rural settlements.

The four constituent Sub-Regions of NCR are given below:

1) Haryana - 40% 13,413 sq. kms. - 9 districts- Faridabad, Gurgaon, Mewat, Rohtak, Sonepat, Rewari, Jhajjhar, Panipat and Palwal	
2) Uttar Pradesh - 32% 10,853 sq. kms. – 5 districts - Meerut, Ghaziabad, Gautam Budha Nagar, Bulandshahr, and Baghpat	
3) Rajasthan - 23% - 7,829 sq. kms. – 1 district - Alwar district	
4) Delhi - 5% - 1,483 sq. kms.	

The population of NCR is projected to be 641.38 lakhs by 2021. Based on the projections & policies given in the Regional Plan-2021 for NCR, it is expected that the population of NCT-Delhi Sub-region would be 225 lakhs by 2021 and 163.50 lakhs, 49.38 lakhs & 203.50 lakhs for Haryana, Rajasthan Sub-region & Uttar Pradesh Sub-regions respectively.

NCR Planning Board prepared a Regional Plan with the perspective for year 2021 for the National Capital Region which was notified on 17.9.2005 for implementation. The Plan aims at promoting growth and balanced development of the National Capital Region. In this endeavor the effort is to harness the spread of the developmental impulse and agglomeration economies generated by Delhi. The above objective is sought to be achieved through:

i.) By providing suitable economic base for future growth and by identification and development of regional settlements capable of absorbing the economic development impulse of Delhi.

ii.) To provide efficient and economic rail and road based transportation networks (including mass transport systems) well integrated with the land use patterns.

iii.) To minimize the adverse environmental impact that may occur in the process of development of the National Capital Region.

iv.) To develop selected urban settlements with urban infrastructural facilities such as transport, power, communication, drinking water, sewerage, drainage etc. comparable with Delhi.

v.) To provide a rational land use pattern in order to protect and preserve good agricultural land and utilize unproductive land for urban uses.

vi.) To promote sustainable development in the Region to improve quality of life.

vii.) To improve the efficiency of existing methods and adopt innovative methods of resource mobilization, and facilitate, attract and guide private investment in desired direction.

The proposed RRTS corridor between Delhi, Ghaziabad and Meerut is envisaged as part of the National Capital Region Planning Board's Regional Transport Plan 2021 for a Mass Rapid Transit System that could provide an effective, high-speed and world class solution to benefit ridership between the cities of Ghaziabad, Meerut and towns of Modi Nagar, Murad Nagar, Modi Puram, Guldhar and Duhai with Delhi. The RRTS corridor has been proposed to create a cost-effective yet world class transportation solution to provide a much needed relief to the NCR commuters and to discourage congestion within Delhi, a city bursting at its seams with inflow of population and strained resources and infrastructure.

0.2. Agency

Delhi Integrated Multi Modal Transit Systems (DIMTS) has been awarded the work for development of Detailed Project Report for the proposed RRTS corridor by NCRPB. As a part of the ongoing assignment, this "Feasibility Report" presents the financial and technical feasibility of the RRTS corridor.

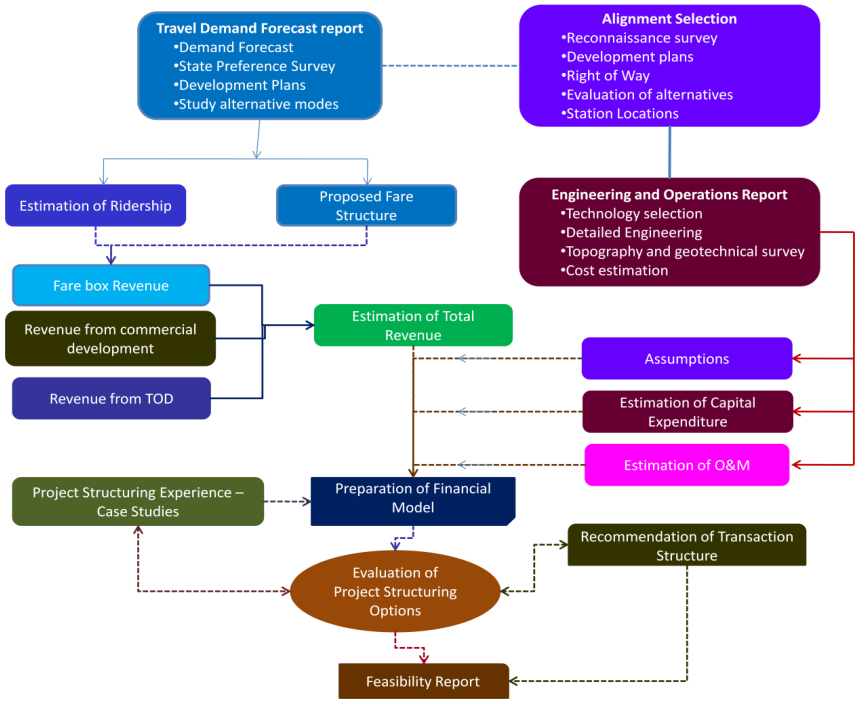
0.3. Vision of RRTS

The vision of RRTS can be summarized in the following points:

- To create an optimized hi-speed high quality transport system having predominantly seated accommodation and good comfort level for passengers
- The operating pattern may include both non-stop and stopping at all stations journeys. The non-stop journey between Delhi and Meerut to be in the order of 45-50 minutes for the RRTS corridor
- The Delhi terminus may be located for interchange with the existing Delhi Metro network or any other separate continuing link with other alignments in the RRTS
- Interchange with other MRTS corridors including the development of feeder systems to other MRTS corridors
- To use Broad gauge track and coaches must meet standard Indian structure profile
- Optimized locations of stations for ease of access to commuters and to serve maximum volume of ridership
- Optimize route, ridership and number of stops so as to achieve good operating speeds.

0.4. Overall Approach for Feasibility

The figure below depicts the overall approach for preparation of the Feasibility Report for the RRTS Delhi- Ghaziabad -Meerut corridor.



0.5. Travel Demand Forecast

Travel demand by various modes is forecasted for all the horizon years 2016, 2021, 2031, 2041.

A detailed Traffic Demand Forecast Study was conducted to determine expected ridership on the proposed RRTS. The study was based on detailed traffic surveys and stated preference surveys which enabled estimation of traffic based on total traffic demand and likely shift on RRTS due to various saving and benefits offered by the system. As part of study various scenarios were built which provided a range of forecasts under various considerations of travel time, travel cost, transit oriented developments and feeder network. The passenger forecasts of final scenario derived under assumptions of feeder network and TOD together with simulated travel time and fares as per willingness to pay survey.

This is based on 62 minutes travel time between Sarai Kale khan- Meerut, peak and off peak frequency as per operational plan and Rs.1.07 per km fare as determined from WTP. The ridership is presented in Table below. The fare between Sarai Kale Khan (Delhi) to Modipuram station has been considered at Rs. 90 based on total length of the corridor.

Sr. No	Year	Ridership per day
1	2016	570,203
2	2021	742,332
3	2031	919,612
4	2041	11,35,530

A concessional fare (monthly pass) has also been considered for the commuters. We have assumed that the concessional fare would be 25% less than the full fare for respective journeys for the consumers. It has been assumed that 75% of the

passengers would be using the full fare and 25% would be using the concessional fare (monthly pass) for commuting between Delhi – Meerut.

In addition, a further analysis was conducted to delineate the TOD zones near to the various stations. The extra inducement of traffic from finalized TOD zones was accounted in revised forecasts.

0.6. Existing Rail and Road Alignment

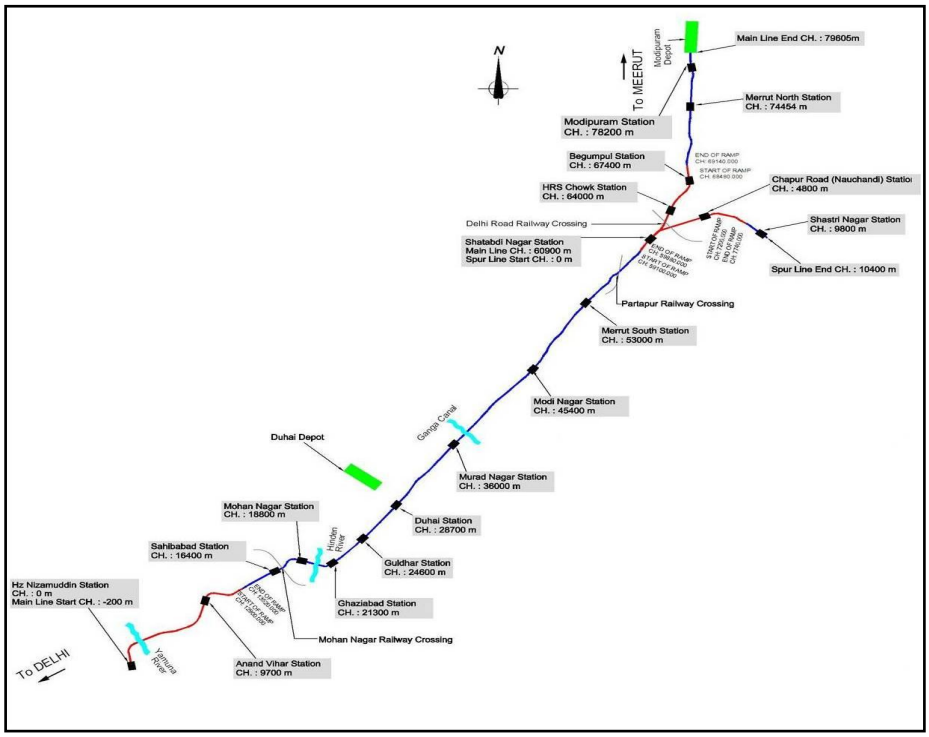
The existing Northern Railway corridor between Tilak Bridge–Sahibabad and Sahibabad-Ghaziabad section is a multiple line electrified section. While the Tilak Bridge-Sahibabad section is a double-line section, the Sahibabad- Ghaziabad route has 4 lines. Maximum Permissible Speed of Tilak Bridge –Ghaziabad section is 110 kmph. These sections of Northern Railway are one of the busiest routes of Indian Railways. The line between Tilak Bridge –Ghaziabad-Meerut is At-grade. It is seen that the Right of Way is generally limited, the section has 42 level crossings and has curves at 30 locations. There are 15 stations enroute which have built up area and are very congested. Line capacity for Delhi – Ghaziabad section is over saturated. In view of very high traffic density between Tilak Bridge and Ghaziabad and other constraints, the use of the existing Indian Railway Corridor for the introduction of RRTS system is not considered feasible.

The National Highway 58/24 connecting Delhi and Meerut generally follows flat or gently undulating terrain at grade with grade separation at two locations. NH 24 has 6 lanes between the Delhi – Mohan Nagar section with the ROW of 66.96 m. Ghaziabad to Partapur section of NH 58 is 4 lane divided highway with ROW of 36.58 m. The ROW for the rest of the section is varying from 49 m to 65m. The townships are developed generally along the National Highway-58, which also has strong potential for Transit oriented Development (TOD) at several places. A good feeder network can be provided if the alignment is build along the National Highway. In areas around Delhi, Anand Vihar and in Meerut because of congestion and other Metro projects under construction, underground options for the RRTS alignment have to be explored. Based on above considerations, alignment was placed along NH58.

0.7. Proposed Alignment

The RRTS corridor will be a double line broad gauge, rapid railway system, built on elevated viaducts and going underground in heavily populated areas. It will connect Modipuram in Meerut to Sarai Kale Khan in Delhi. A spur will take off from Shatabdi Nagar to Shashtri Nagar in Meerut The viaduct will be built along the central median of the National Highway connecting Delhi to Meerut, wherever feasible. The route length of the corridor is 90.2 Kms, with 59.08 Kms elevated and 30.12 Kms underground track.

Following provides corridor length, proposed stations along the corridor and type of station.



Corridor length and stations

Sr. No	Stations	Elevated	Underground	Total
	Project Start	0.000	0.200	0.200
1	Sarai Kale Khan – Anand Vihar	0.000	9.700	9.70
2	Anand Vihar – Sahibabad	3.240	3.460	6.700
3	Sahibabad – Mohan Nagar	2.400	0.000	2.400
4	Mohan Nagar – Ghaziabad	2.500	0.000	2.500
5	Ghaziabad – Guldhar	3.300	0.000	3.300
6	Guldhar – Duhai	4.100	0.000	4.100
7	Duhai – Muradnagar	7.300	0.000	7.300
8	Muradnagar – Modinagar	9.400	0.000	9.400
9	Modinagar – Meerut South	7.600	0.000	7.600
10	Meerut South – Shatabadi Nagar	6.480	1.420	7.900
11	Shatabadi Nagar – HRS Chowk	0.000	3.100	3.10
12	HRS Chowk – Begumpul	0.00	3.400	3.400
13	Begumpul – Meerut North	5.634	1.420	7.054
14	Meerut North- Modipuram	3.746	0.000	3.746
	Main Line Ends	1.405	0.000	1.405
	Spur Line			
15	Shatabadi Nagar – Hapur Road (Spur)	0.00	4.800	4.800
16	Hapur Road – Shastri Nagar (Spur)	2.380	2.620	5.000
	Spur Ends	0.600	0.000	0.600
	Total	**60.085**	**30.120**	**90.205**

0.8. Transit Oriented Development Zones

A transit-oriented development (TOD) is a mixed-use residential or commercial area designed to maximize access to public transport, and often incorporates features to encourage transit ridership. A TOD neighborhood typically has a center with a transit station or stop (train station, metro station, or bus stop), surrounded by relatively high-density development with progressively lower-density development spreading outwards from the center.

Various potential TOD sites were identified in vicinity of station areas where vacant land exists. While the small land pockets identified in at Mohannagar, Ghaziabad, Shatabdi Nagar and Shastrinagar are government land other large sites identified at Modipuram, Meerut south, Duhai and Gudhar belong to private property. While the smaller plots near to the stations were planned along with the station areas for larger TODs, design guidelines and typical initial master concept plan has been prepared which could help in guiding the land-use as per the requirements. The table below provides potential TOD locations along the corridor. The figure indicate location of TOD.

S. No	Location	Area Required (Hectares)	Type
1	Modipuram (Depot)	400	Mix
2	Shastri Nagar	2	Commercial
3	Shatabdi Nagar	2.4	Commercial
4	Meerut South	400	Mix
5	Duhai	400	Mix
6	Guldhar	250	Mix
7	Gaziabad	4	Commercial
8	Mohannagar	4	Commercial
Total Area		**1458.4**	

Modipuram (Depot) & Proposed TOD Area

Proposed Meerut South TOD Area

Proposed Duhai TOD Area

Proposed Guldhar TOD Area

0.9. Operational Specifications

The operational specification for the Delhi – Meerut Rapid Rail Transit System were prepared based upon the known requirements for infrastructure, rolling stock and the forecasted demand. Various options of timetabling were examined and for each of these options, the various parameters such as running time, infrastructure configuration, service specification, time tables were assessed:

The finalized option with 160 Kmph speed, 6-9 coaches per train, coach size 24 metres x 3.66 metres was adopted for analysis. RailSys software was used for simulation in this project. The Siemens Desiro train model suitably adjusted for the RRTS speeds and coach size has been used in the simulation.

Running Time

The simulation results for train running time showed that the maximum speed of 160 Kmph for the RRTS trains is the best to achieve the client's aspiration of having a non stop journey time of about 45 minutes between Meerut and Delhi. As the speed increases from 120 to 140, there is a reduction of almost 2 minutes in the running time which further increases to about 3 minutes at 160 Kmph. Further increase of speed to 180 Kmph reduces the time by only 33 seconds and therefore is not desirable considering the additional costs and maintenance efforts needed. The recommendations are:

- Maximum speed of trains: 160 Kmph with design speed of rolling stock 180 Kmph
- Journey time Modipuram to Sarai Kale Khan with halts at all stations: 62 minutes

Train Capacity

The coach size was finalized as 24 m long and 3.66 m wide. The seating was planned as 3 + 2 airline type with standing passengers at 3 persons per square

metre. One space in the coach was reserved for wheelchair passengers. Based on this the capacity of 6 coach and 9 coach trains were calculated as 206 passengers for a Driving Car and 225 for a Trailer Car.

Dwell Times

The dwell time at stations was determined by observation of the door opening and closing cycle as well as the time taken by passengers to exit and enter from one door of Delhi Metro trains. A door cycle time of 15 seconds was taken and the rate of boarding/alighting per door of the coach was taken as 1.5 persons per second. Based on this, the maximum dwell time was found to be 47 seconds at Ghaziabad which is the station having the highest number of passengers.

Service Frequency

The simulation study revealed that demand can be met in the years 2016 and 2021 by running 6 coach trains and in years 2031 and 2041 by 9 coach trains. The peak hour frequency will be 12 trains per hour in 2016 and 2021 and 14 trains per hour in 2031 and 2041.

Service frequency was estimated for servicing projected traffic loads as shown in Table below. For timetabling purpose 15 trains per hour have been assumed instead of 14, to avoid fractions of minutes in time tabling and also to have some cushion. In the years 2021 and 2041, additional service will be required between Guldhar and Sarai Kale Khan to accommodate the passengers between these two locations.

Service frequency by horizon year and specified train formation per direction:

Horizon year	6 car train	9 car train
2016	12 tph	8 tph
2021	14 tph	10 tph
2031	17 tph	12 tph
2041	21 tph	14 tph

As per above estimates 4-5 minutes frequency shall be adequate till 2021 with 6 car train and by 2041 with 9 car train.

0.10. Rolling Stock Requirement

Different types of Rolling Stock that can be used on the RRTS were examined from the aspect of ability to satisfy operational requirements, compatibility and interface with infrastructure and whole life cycle costs. After analysis of the vehicle types, it was decided to adopt Electrical Multiple Units (EMU) with overhead traction power supply since these were found to be most suitable. The main reason for preferring the EMU option was that it met the journey time requirements, particularly with a stopping service where high acceleration and braking rates are required. An EMU is also likely to provide a lower whole life cost due to its lower mass, efficient traction system and ability to regenerate power into the OHE. This preference is also supported by the fact that a large proportion of similar commuter services across the world are operated by EMUs. World over there are several manufacturers of EMU like Bombardier, Alstom, Siemens, Stadler, CAF, Rotem, Talgo, Hitachi etc. who can supply EMUs to the RRTS specifications.

After examining various options for the size, seating capacity, number of doors etc, and extensive discussions with the client, the broad details of the EMU were finalized. These are given in the table below.

Requirement	Value
Track gauge	1676 mm
Traction power	25 KV, 50Hz overhead line
Regenerative braking	Provided
Vehicle length over couplers	24 m
Vehicle external width	3.66 m
Nominal height of the coach	3.9 m
Number of doors on each side of coach	3
Door width	1.5m
First class accommodation	No
Wheelchair space provision	1 per vehicle
Planned standing density	3 persons per square metre
Seating configuration	transverse rows of 3+2
Seat pitch	80 cms
Axle load	20 tonnes
Train lengths	6, 9 cars
Train composition 6 coach	DMC TC MC MC TC DMC
Train composition 9 coach	DMC TC MC MC TC MC MC TC DMC
Maximum speed	160 kph. Design speed 180 kph
Acceleration/ emergency decelaration	1 metre per sec^2 / 1.3 metres per sec^2
Capacity of one Driving coach	91 seats, 115 standing, 1 wheel chair
Capacity of one motor/trailer coach	101 seats, 124 standing, 1 wheel chair
Emergency passenger evacuation	Through front of driving cab

The number of units required is based upon the number of ECS moves used to form the first passenger trains of the day. This amounts to 28 to which we recommend a 10% contingency be added leading to a total of 31 units required in 2041. The table below gives the number of EMU coaches required in different years of operation.

Year	No. cars / train	tph	Units	Driving cars	Non driving cars	Total cars
2016	6	12	28	56(56)	112(112)	168(168)
2021	6	15	31	62(6)	124(12)	186(18)
2031	9	12	28	56(0)	196(72)	252(72)
2041	9	15	31	62(0)	217(21)	279(21)

The capacity of train are as under.

No. of cars	Total capacity
6	1314 + 6 wheel chairs
9	1990 + 9 wheel chairs

Driver Numbers

The number of drivers required is worked out as 142 based on various assumptions

Depot and Stabling Plan

There will be a depot-cum-workshop at Modipuram and a sub depot at Duhai. All rolling stock will return to either Modipuram or Duhai Depot for overnight cleaning and servicing. The following table shows the stabling requirements at both depots in 2041.

Year	Modipuram Depot	Duhai Depot	Total
2041	21(includes 3 spare)	10	31

One train each out of the above can remain stabled at Modipuram and Duhai station platforms at night and commence the working from the station itself next day. Sweeping of the train can be done at the platform. Given that the facilities differ between depots it is important that the diagrams are rotated so that each train set visits Modipuram depot on a regular basis for maintenance.

Infrastructure and Operational Requirements were also assessed. This consists of stations, platforms, loop lines, crossovers and maintenance depots at Modipuram and Duhai.

There are certain operational requirements of the signalling, electrification, communications systems and stations. These include the capability to support train running at 160Kmph, ability to use one line while the other is blocked, having a control centre with SCADA etc determined from operational plan.

0.11. Communication Systems

The Communication System provides the necessary subsystems to support the total operation requirements of a rail system. The Communication System has to be a highly resilient system commensurate with the operational philosophy proposed for the RRTS.

After comparing the different options, the following were recommended for the RRTS:

- Control Centre with high degree of centralization
- Transmission backbone: Gigabit Ethernet
- Mobile Radio Communication: TETRA
- Station Systems: PIS, PAS, PHPs and LAN
- CCTV: Targetted coverage
- Train Dispatch: Driver Only Operation with on board cameras and monitors
- Blue Light Stations: At cross passages, crossover tracks, platform end walls, emergency exits etc.
- Power distribution system for communications: With 3 hour battery backup

0.12. Automatic Fare Collection System

An Automatic Fare Collection System (AFCS) is a method of providing automated revenue management. An AFCS facilitates the purchase of pre-paid tickets that can be used to permit access to /from various transport modes through the use of

electronic systems and thus eliminating all human error and confrontation. An AFCS also provides valuable information for the management of the transport system and helps to enforce the safety and security policy of the transport system.

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For the RRTS, the proposed ticketing system shall be Automatic Fare Collection with Contactless Smart Token/ Cards. Equipments for the system shall be provided at each station and will be connected to a local area network with a computer in the station Master's room. The AFS System for the RRTS should have the following features:

Item	Requirement
Ticket	Contactless Smart Token – For single journey. They shall have stored value amount for a particular journey. Tokens will be captured at the exit gate. Contactless Smart Card – For multiple journeys. Can be recharged at stations or remotely.
Gates	Retractible flap type, computer controlled automatic gates at entry and exit. The gates will be of following types: Entry Exit Reversible – can be set to entry or exit Handicapped – wide reversible gate for disabled people.
Station computer, Central computer and AFC net work	The AFC equipments shall be connected in a LAN with a station server controlling the activities of all the machines. These station servers will be linked to the central computer situated in the OCC through the communication channels. The centralized control of the system shall provide real time data of earnings, passenger flow analysis, blacklisting of specified cards etc.
Ticketing machine	Manned Ticket office machine shall be installed in the stations for selling cards/ tokens to the passengers. There will also be Passenger Operated Machines at the station for automatic ticket vending.
Ticket reader and portable ticket decoder.	A ticket reader shall be installed near the ticket vending machine for passengers to check information stored in the token / cards.
UPS (uninterrupted power at stations as well as for OCC).	The UPS of the S&T system will be utilized for emergency power supply to the AFCS.

0.13. Electric Power Supply

The RRTS requires electrical power for operation of the trains, running the station services like lighting, lifts, escalators, operating the signal & telecommunication system, depots and other infrastructure. The most important requirement is the traction power supply.

The 25 KV AC and 2x25 KV AC traction systems were examined in greater detail as they were the most appropriate for the RRTS.

The 25 KV AC overhead line system is recommended for the RRTS. 25kV A.C. 50 Hz traction power supply overhead line is now the standard voltage in India with over majority of the electrified network in this form and is the most suited to this type of railway system, because this has a number of benefits including system familiarity (construction and maintenance); availability of spare parts; and usage worldwide on high speed railways. The 25 kV A.C. system of traction emerged as an economical system of electrification as a result of extensive research and trials in Europe.

The 2x25kV (AT) system, offers increased power availability to supply heavier demands, an increase in the distance between feeder substations, or a combination of these benefits. This could reduce the number of feeder stations required and could offer cost saving. This saving will not be fully realised on the Delhi – Ghaziabad – Meerut Corridor as there must be sufficient spare capacity in the event of one substation or supply point failure - that is, it should be possible to keep the train service operating even if one substation is completely out of service. The saving of substation cost will not be more than one considering route length and minimum requirement of substations. Hence 25 kV AC electrification system has been recommended for RRTS.

0.14. Power Requirement

The power will be supplied to the rolling stock through a flexible catenary in elevated sections and a rigid catenary in underground sections. Sectioning posts and sub sectioning posts will be located at appropriate intervals. The design capacity for traction power has been calculated.

In addition Auxiliary power is required for station mechanical and electrical services, depots, tunnel ventilation, illumination and airconditioning of service buildings, yard and tunnel lighting etc. The requirement of auxiliary power has also been calculated

The total power requirement is presented below:

Particulars	2016	2021	2031	2041
Total Traction Load MVA	41.33	49.22	66.74	**73.37**
Total Auxiliary Load MVA	34.20	36.73	44.21	**47.42**
Grand Total MVA	**75.53**	**85.95**	**110.95**	**120.78**

The sub stations will need to have capacity to meet the power requirement of 2041.

0.15. Location of Receiving Sub-Stations

Based on the above power requirements it was decided that the RRTS will have 4 receiving sub stations of about 40 MVA capacity each, including one standby so that if one sub station fails, the train operations can still continue. Discussions were held with the electricity authorities of UP Power Transmission Corporation Ltd. and Delhi Transco Ltd. to determine from where they can supply power from their grids. Based on the discussions, the location of the RRTS receiving Sub Stations were finalized at the following locations:

S. No.	Receiving Sub Station (RSS)	Supply from Grid Sub Station (GSS)
1	Shatabdi Nagar (Jagran Chowk) 42 MVA	220 KV SS at Shatabdinagar from UPPTCL
2	Muradnagar (NH 58) 40 MVA	400 KV SS at Muradnagar II from UPPTCL
3	Ghaziabad (NH 58) 40 MVA	400 KV SS at Ator from UPPTCL
4	Sahibabad (NH 58) 40 MVA	400 KV SS at Indirapuram from UPPTCL
5	Delhi (Sanjay Lake) 40 MVA	220/33KV SS at Anand Vihar from Delhi TRANSCO

The preferred locations of the four Receiving Sub Stations are at Shatabdi Nagar, Muradnagar, Ghaziabad and Sanjay Park. Sahibabad has been selected as an alternative in case Delhi is unable to supply the required power.

0.16. Permanent Way

The features of the Permanent Way selected for the RRTS are described below.

Track Gauge and Axle load

The RRTS will have Broad Guage (1676mm). The design axle load is finalized as 20 tonnes, and the track therefore needs to be designed for this axle load.

Rails

It is proposed to have Continuous Welded Rails (CWR) for the RRTS. CWR has the following advantages over conventional fish plated track:

- It ensures better safety since there is no possibility of fish plates opening or being tampered
- It provides more riding comfort with less noise and vibrations.
- It requires less maintenance

The current practice is to have switch expansion joints at regular intervals on the CWR, in order to determine if there are any thermal stresses built up and relieve the same without having to cut the rails. For the RRTS it is recommended that the SEJs should be at 2 kms intervals.

The rails should be welded by flash butt welding, which can be done easily nowadays by mobile welding plants. Thermit welding should be used only where flash butt welding is not possible for some reason.

The rail is recommended to be UIC 60 head hardened rails conforming to grade 1080 as per Indian railway Specification IRS T-12-2009 with elastic fastening at 60 cms apart on the viaduct and in tunnels. In depots, 60 Kg rail with 90 UTS can be used with spacing of 65 cms for fastenings.

Track Structure

The RRTS track will be subjected to intensive use with little time for day to day maintenance. Therefore the track structure should be long lasting, require little maintenance, be safe and reliable and give a comfortable ride.

The track can be conventional ballasted track, or ballastless. For the RRTS, ballastless track is recommended on the elevated viaduct and underground tunnels for the following reasons:

a) Less maintenance requirement due to the fixed position of the track. There are also fewer components, most notably sleepers and ballast, that require maintaining. This is beneficial not only regarding cost but also in the reliability of the track system, with reduced risk of service affecting failure, and ultimately safety. The requirement of specialized track maintenance machines is also less.
b) The weight of concrete track is less than conventional ballasted track and this will have a significant bearing on the cost of supporting structures. Since there is a considerable length of elevated section on the RRTS there will be substantial cost savings due to use of ballastless track.
c) The cross section space in tunnels is limited. Concrete track has two advantages. The construction depth of ballastless track is generally less than that of ballasted track and therefore, greater vertical clearance can be achieved. Secondly, by virtue of its fixed position, allowances in clearances for movement of the track need not be as great as those for ballasted track.
d) Whole life costs of ballastless track are becoming more competitive. A cost comparison was undertaken in 2009 as part of a feasibility study and outline design for track on part of the Crossrail project in the UK showed that the whole life cost of ballastless track was approximately 1.15 - 1.3 times that of ballasted track. With the other advantages of ballastless track this is acceptable.

In depots, the track will be ballastless as well as ballasted. Ballastless track in Depot may be of the following type:

- Discretely supported on concrete/steel pedestal for inspection lines.
- Embedded rail type inside the workshop.
- Plinth type for washing plant type.

Ballasted track in depots will be provided at other than washing and inspection lines. This will be of PSC sleepers 60kg rail with elastic fastening system. Spacing of sleepers on those tracks can be 65 cm from centre of sleeper to centre of adjacent sleeper.

Track Fittings

Rail fasteners can be of conventional type with elastic fastenings which are commonly used on Indian Railways track, or direct fastening of Track to fixed infrastructure. The conventional fastenings have their limitations – the rail clips are prone to theft, they can break due to sudden variation of temperature their elasticity is diminished slowly on track resulting loss of toe load and it comes out from sleepers due vibrations of train movement. This type of fitting requires constant watch by P Way staff everyday.

The direct fastening method is commonly used on structures where it would be problematic to install ballast (like elevated viaducts), or be difficult to clean and maintain (like tunnels) or where there are structural issues. It is also used where tight clearances to structures demand minimal movement of the line and level of the rail head.

It is recommended to use Vossloh – 336 fastening system on the ballstless track of the RRTS as this system has proved itself in Indian conditions. This system is found to be efficient as it is directly fixed on plinth of the track by iron base plate, rubber pads and elastic Vossloh 336 type fastening by means of bolts through pre-cast holes. These can be tightened in such a manner that it does not become loose due to vibrations of wheels. Moreover, a spring type arrangement is there, so that clips are firmly fixed on the rail foot all the time.

0.17. Singnalling

Various possible options of modern signaling systems were evaluated, these includes:

- ETCS Level 2
- French TVM
- Continuous Automatic Train Control System (CATC)

Considering the likely difficulty in getting the required radio frequency from the government, it was decided to use Continuous Automatic Train Control System of signalling for the RRTS at present stage. At the time of procurement, the review of latest signalling technology could be undertaken and possibility of adopting latest communication based signal systems could be explored.

CATC provides a high level of safety with train running at close headway ensuring continuous safe train separation. CATC is capable of achieving functional, operational and safety requirements almost similar to ERTMS level 2. The only difference is that continuous communication between trackside equipments and train is through track using coded Audio Frequency Track Circuits, instead of through radio.

0.18. Civil Engineering

Viaduct

The majority of the RRTS track is going to be on elevated viaduct. An analysis of the techno-economical features of the various available viaduct options was conducted to recommend the most beneficial option.

The Options for the viaduct section selected are based on the requirement of Fast Track Construction as is envisaged for Projects of this nature and magnitude. The emphasis while selecting various options has been on the reduced construction time, ease of construction and standardized construction methodology. Keeping this in view the superstructure arrangements which can be completely pre-cast are chosen as options and that involve cast-in-place components have been rejected.

Three options were studied wherein the casting operation are restricted to the Casting yard while at site only erection and launching operations are required thereby making the full standardization and mechanization of construction of superstructure possible. The options are:

- Precast Pos-tensioned Segmental Box Girder
- Precast Pos-tensioned Segmental Single U girder
- Precast Full span Pre-Tensioned Double U girder

The first two options are suitable for precast Post-tensioned segmental launching as the weight of full span precast girders is very high which shall create difficulty in handling during erection.

The third option i.e. double U shaped girder is suitable for full span launching as the weight of one part is approximately 180T for a span of 30 m and width is 5.6m. However this requires specially designed trailers and launching cranes/system.

Cost comparison of three options is as under:

Substructure Type	Cost in Crores per Km		
	Option-1 (Box Girder)	Option-2(Single U)	Option-3 (Double U)
Standard Height Pier Section	27.354	29.151	24.922
Portal Pier Section	39.424	39.927	34.872
Double Height Pier Section	31.786	33.368	28.643

The double U option with full scale launching is the fastest and most economical option for the construction of the viaduct. The scheme is so fast at casting yard as well as launching at site that no segmental launching option matches it in merits.

However major disadvantage of this is option that design of U shaped viaduct for railways have been patented by M/S Systra of France internationally as well as in India. Since the financial and other issues at this stage are not known for the patent issues, box girder with segmental launching is recommended for RRTS viaduct at this stage.

The special substructure arrangement is required where the RRTS alignment is in the carriageway of the road underneath. They are

- Cantilever pier cap
- Portal Piers

There are several proposed flyover and elevated viaducts along the alignment especially in Muradnagar and Modinagar. At these locations double height pier is required.

The standard spans suffice the purpose for most of obligatory crossings except for three locations where special spans are required. These spans have been proposed with extra-dosed option instead of balanced cantilever construction. Although the construction methods of both are identical extra-dosed option is preferred as it involves very less deck depth and are very elegant appearance. The costing of both options is approximately similar, the location of special spans are shown below:

Ch From	Ch To	Span arrangement
36597.667	36792.667	75+120+75
46870.000	47016.000	56 +90 +56
56380.000	56545.000	65 +100 +65

Tunnels

About 30 Kms of the RRTS route is going to be underground which will require tunnels to be constructed.

Base on the analysis of various parameters and site conditions following tunnel parameters proposed.

Method of excavation	:	Mostly tunnel boring machine; cut-&-cover in small tunnel reaches
Number of tunnels	:	Two parallel tunnels with single track in each tunnel
Shape of tunnel cross-section	:	Circular
Tunnel size	:	Finished diameter = 6.7m;
Depth of tunnels	:	15m below ground surface and 15m below river bed
Clear spacing between tunnels:		15m between outermost edges of the two tunnels

Ventilation

The ventilation and smoke control systems for the project include the following:

- Stations ventilation systems – public
- Stations ventilation systems – back-of-house
- Stations smoke control systems
- Tunnel ventilation and smoke control systems

Ventilation systems are required to achieve the following:

- To maintain comfort conditions in public and back-of-house areas of the station through removal of heat from trains, plant and people
- To provide smoke control in stations, generally through smoke extract systems.
- To maintain temperatures within the tunnels such that comfort conditions can be maintained on trains. The requirements include the stopped train condition.
- To provide smoke control within tunnels in the event of a fire, usually by longitudinal ventilation between ventilation points. This includes protection of non-incident trains and passengers on stations from the effects of smoke from a train fire.
- Provide outlet of air if the air pressure becomes too high due to the piston effect of moving trains.
- Extract smoke in case of a fire in the tunnel
- Direct air flow in a particular direction, away from the side where passengers are evacuating, so as to prevent flames from reaching the passengers.
- Provide cooling if the ambient temperature in the tunnel reaches beyond an acceptable limit.

The tunnel ventilation system (TVS) will consist of fans, dampers, attenuators and associated ductwork located at the ends of the stations and at intermediate ventilation shafts as required. These ventilation points will divide the tunnels into aerodynamic sections for smoke control.

i) Tunnel ventilation

Tunnel Ventilation System (TVS) will be provided for tunnels and trackways of the RRTS underground stations to maintain an acceptable environment during normal and congested operation conditions, and to handle smoke control for safe evacuation of passengers during fire emergency (or incident) condition in the tunnels and stations' trackways.

The Tunnel Ventilation System will comprise trackway ventilation system and tunnel ventilation system. The trackway ventilation system will be used to ventilate the station's trackways, whilst the tunnel ventilation system to serve the adjoining tunnels. Tunnel ventilation system is designed to meet the requirements at all operation scenarios. The scenarios are normal, congested and fire emergency operation.

Station Ventilation system

Station trackway exhaust system has been proposed to remove the heat generated by the train air-conditioning system and the braking equipment, as well as to extract smoke in case of a train fire at station.

Air-conditioning and mechanical ventilation systems will be provided to serve the Back-of-House (BOH) areas, E&M plant rooms, and systemwide plant rooms. Air conditioning will be provided by either floor mounted AHU's or fan coil units. Dynamic smoke control system will be designed for underground stations and Static smoke control system will be designed for above ground stations.

0.19. Alignment Proposal

The design of proposed RRT corridor includes proposals of Tunnel sections, elevated sections on standard cross sections & spans, special spans and double elevated special composite structures at certain locations where elevated road is proposed (Modinagar & Muradnagar).

0.20. Operations and Service Delivery

The operations and maintenance plan outlines the preliminary provisions that will need to be made in order to enable the RRT system to function and operate effectively. Main objectives of the O&M plan are:

- Trains will operate on the RRTS for 18 hours a day from about 5 am to 11 pm.
- The Operator of the RRTS system will require an operations organisation with individuals having specific roles and responsibilities. This will ensure that all the major activities are assigned and communication lines and responsibilities are established. The roles in the organization will be:

  a) Operations Management
  b) Train Operations
  c) Rail System Operations
  d) Station & Tunnels operations
  e) Health, Safety, Environmental, Security and Quality
  f) Customer Service / Public relations
  g) Contract, Revenue & Finance

- The RRT will require detail operational and communication mechanism to ensure services as per requirements. All these various methods will be provided so that critical communications are always possible. The communication systems within the OCC will be protected and backed-up with hot standby equipment so that partial failure is unlikely and total failure impossible. Telephones will be available on all station platforms for the use by station staff, maintainers and other authorised persons to communicate with other parts of the RRTS network including the operational control centre and maintenance depots. Help points will be provided at strategic locations within stations for the public.
- Access into the stations by emergency service will be facilitated by using designated entrance points and having staff marshall the public away from such access points and routes. Each station will have specific plans and procedure for the emergency evacuation of passengers.

- All degraded and emergency situations will need to be considered in the design process so that any affect on the infrastructure can be incorporated. Operation procedures and special instructions shall be developed for action to be taken in case of emergency.

0.21. Maintenance

The strategy and philosophy for maintenance of the RRTS assets has been derived from the need to maintain a modern, intensively utilized railway system like the RRTS, with the least cost, minimum down time and maximum safety of the system. The important aspects of this strategy are highlighted below.

- More emphasis must be placed on mechanized maintenance as compared to traditional manual labour based maintenance.
- More emphasis must be placed on asset condition monitoring.
- There will be higher proportion of skilled staff and less of unskilled staff and majority of Staff will need to be multi-skilled.
- Maintenance will be performed in-house for crucial and safety related items–P Way, OHLE, Rolling Stock and Signal equipment. Some ancillary items may be outsourced.
- The maintenance will be preventive maintenance where activities are undertaken on a predetermined time interval.
- The condition of the asset will be monitored regularly through telemetry techniques or, through a manual process of inspections.

An integrated maintenance depot will be set up at Modipuram to undertake maintenance of Rolling Stock as well as S&T, Electrical and Civil engineering equipments. A sub depot at Duhai will also be set up, mainly for stabling trains but also for carrying out petty repairs or emergency repairs.

The maintainer of the RRTS system will require a maintenance organisation with individuals having specific roles and responsibilities. This will ensure that all the major activities are assigned and communication lines and responsibilities are established.

All crucial safety related maintenance work must be done in house with trained staff of the RRTS. Some non core activities like building maintenance, electric sub station maintenance, road transport, housekeeping work etc. can be outsourced to private parties.

Maintenance of certain assets like the signalling system, rolling stock etc can be given to the supplier of the system, but this must be covered by strict contractual obligations and responsibilities in case of accidents.

Annual maintenance contract must be given for sophisticated sub systems like computer network, S&T equipment modules, POH of track machines and locomotives etc. The work done by the private parties must be strictly monitored by the RRTS staff.

Renewal of assets must be done after their economic life is over. The time of renewal will depend on the condition, the stated life of the asset as per the manufacturer, intensity of use etc. The Indian Railway Finance Code which lays down the codal life of Railway Assets can be a guide to determine replacement.

The maintenance practice to be adopted for major sub systems like P Way, OHE, Rolling Stock, S&T including suggested maintenance intervals shall be followed for smooth operation. Key performance indicators for the RRTS have also been suggested to measure the effectiveness of the maintenance practices in ensuring a reliable RRTS service.

0.22. Depots

For the Delhi – Meerut RRTS corridor, it is proposed to have integrated maintenance depots for stabling and repair of rolling stock, as also for maintenance of electrical, signal, communications and permanent way equipment. The primary function of the depot will be to maintain rolling stock and major facilities.

There will a main depot at Modipuram and a sub depot at Duhai. Modipuram depot will undertake all work upto the overhaul of rolling stock while the Duhai sub depot will mainly be used for stabling and cleaning of trains.

The following activities are planned in Modipuram depot:

- Repair and Maintenance of Rolling Stock
- Repair and Maintenance of PWay and rail based OHE equipment like Tower Wagons, Motorized Elevated Platforms,
- Repair and Maintenance of Accident Relief Train, Diesel/Battery Locomotive, Engineering Trains
- Repair and Maintenance of all Mechanical, Electrical, S&T, P Way, ART and miscellaneous equipment, machinery and plant
- Repair and Maintenance of Depot M&P and equipment

Since substantial passenger traffic is between Ghaziabad and Delhi, there is need to run trains exclusively between Ghaziabad and Sarai Kale Khan as brought out in the operations study. To stable these trains during non peak and night hours, stabling lines are needed. Ideally these lines should have been at Ghaziabad, but due to space constraints, this is not possible. Therefore this provision is being made at Duhai where land is available. A sub depot at Duhai is therefore planned.

The Duhai depot will primarily be used for stabling, cleaning and inspection of rolling stock. Some minor repair work of rolling stock and equipment related to P Way, S&T, OHE that can be done without taking the coach or equipment to Modipuram will also be done here.

The Duhai sub depot will need to accommodate stabling of 10 trains, as has been determined by the operations study. One train can be stabled at the loop line at Duhai station. The remaining 9 trains will require 9 stabling lines at Duhai depot. Each line will be of 310 metre length, sufficient to accommodate one train. There will be one line for stabling the Accident Relief Train.

0.23. Stations

The RRTS will have elevated as well as underground stations. Four station typologies were developed to categorized various stations planned for RRTS. The station typologies included following

- Elevated Stations in the middle of the Road
- Elevated Stations on the side of the Road
- Under-ground/underground with Island Platform
- Under- ground stations with Two Islands and Four Lines

Type of stations was decided based on specific requirements. Various required facilities were identified and provided at each station. Platform size was assessed at each station considering passenger load and expected train length. Stations were planned to accommodate sufficient space for commercial exploitation for revenue generation

0.24. Financial Analysis - Assumptions and Boundary Conditions

A detailed financial analysis has been conducted for the project. The various assumptions and boundary conditions adopted for the analysis are given below.

Sr. No.	Particulars	Value
1	Base year for cost estimation	2011
2	Award of contract	October 2012
3	Years of construction	4
4	Commercial operation date (COD)	1st October 2016
5	Concession period/model period	30 years
6	End of concession period/model	30th September 2046
7	No. months in a year	12
8	No. of days in a year	350

Sr. No.	Particulars	Rate (%)
1	Custom Duty	18.6%
2	Excise duty	8.2%
3	Value Added Tax	12.5%

Sr. No.	Particulars	Value
1	Inflation rate	5%
2	Discount rate	10%
3	Tax rate	32.45%
4	MAT	20.01%
5	80IA benefit taken from date	From COD
6	Tax holding in a block of 15 years	10 years
7	Interest Rate for long term borrowings (soft loan)	2%

Sr. No.	Particulars	Value
8	Tenure – soft loan	20 years
9	Moratorium – soft loan	Nil
10	Interest Rate for future CAPEX	10%
11	Loan Tenure – future CAPEX	10 years
12	Debt : Equity Ratio – future CAPEX	80 :20

Standard taxation workings at the prevailing rates have been assumed for the financial analysis. Provision under section 80 I (A) has been considered as the project qualifies for such benefits.

0.25. Revenue Estimation

Fare Box Revenue

Fare box revenue has been estimated based on projected traffic and recommended fare levels. For RRTS fares between the stations are based on telescopic fare structure with a minimum fare 25% of Delhi Meerut Fare (Rs 90). A rebate of 25% on the journey fare is considered for the commuters opting for the monthly pass. The table below presents mode wise comparison of fares.

Sr. No.	Mode	Delhi – Meerut fare (in Rs.)	Journey Time
1	Train -AC Chair Car (Delhi - Meerut City/Meerut Cantt)	165 (71 km)	Shatabdhi :1 hr 15 min,
2	Express Train -Sleeper Class (Delhi - Meerut City/Meerut Cantt)	140 (71 km)	2 hr 10 minutes
3	State Transport bus (Non AC)	56 (67 km)	2.5 hrs
4	State Transport AC Volvo Bus	246 (67 km)	2.5 hrs

Other Revenue

The revenue from other sources is estimated from the following sources :

- Commercial area/ complexes developed at the station complex
- Advertisement panels
- Cess on Transit Oriented Development zones.

The proposed cess from TOD is presented below.

Sr. No.	Description	Unit	Rate
			Rupees
1	Land /Site/Plot	Per sq.m / transaction	1,000
2	Developed Area		
a	Residential	Per sq.m/ transaction	1,000
b	Commercial	Per sq.m/ transaction	2,000
c	Office	Per sq.m/ transaction	1,500

Following table provides summary of revenue streams and total estimated project revenues for 2018, 2021, 2031 and 2041.

Sr. No.	Revenue Stream	FY2018	FY2022	FY2032	FY2042
		Rs. Million /Year			
1	Fare box	8,476	12,873	26,434	52,831
2	Commercial areas at stations	45	62	102	167
3	Commercial areas at secondary buildings	894	1,292	2,104	3,427
4	Advertisement Panels	85	129	264	528
5	Transaction Cess on TOD post construction	5,654	5,277	4,146	2,482
	Total Project Revenue	**15,154**	**19,633**	**33,050**	**59,435**

0.26. Capital Cost Estimation

The capital cost of Delhi – Meerut of RRTS has been estimated by determining the infrastructure and land requirement from Engineering and Operations Report and suitable rates of various items. This is presented below in table.

Item	Description	Units	Quantity	Rate	Total
				Rs. Crore/ per Unit	Rs. Crore
1.0	**Land**				**1,656.75**
1.1	Private Land	Hectare	330.8	5.00	1,653.75
1.2	Rly Land	Hectare	0.1	0.00	0.0
1.3	Casting Yard	Hectare	25.0	0.01	3
1.4	Government land	Hectare	26.2	0.00	0.0
2.0	**Civil works, Alignment and formation (excl. Stations & Depot)**		84.02		**5,758.94**
2.1	Tunneling Work	R Km	24.20	152.86	3,699.2
2.2	Ramp - underground	R Km	1.30	47.35	61.6
2.3	Ramp - Elevated	R Km	1.58	18.52	29.3
2.4	Elevated Viaduct	R Km	53.02	30.00	1,590.5
2.5	Underground section by Cut & Cover excluding Station length	R Km	2.30	107.23	246.6
2.6	Special Spans	R Km	0.70	47.61	33.4
2.7	Underground loop lines	R Km	0.92	107.23	98.2
3.0	**Station Building (incl. Commercial area)**		17.000		**2,393.56**
3.1	Underground Terminal	Nos.	1.0	125	125.0

Item	Description	Units	Quantity	Rate	Total
				Rs. Crore/ per Unit	Rs. Crore
	station				
3.2	Underground Station	Nos.	5.0	207	1,036.5
3.3	Elevated Stations	Nos.	9.0	116	1,042.5
3.4	Elevated Terminal station	Nos.	2.0	95	189.6
4.0	**E&M Works**		17.000		**745.47**
4.1	Electro mechanical works including Lifts, Escalators, DG sets, UPS,TVS, ECS				
4.1.1	Underground station	Nos.	6.0	67.33	404.0
4.1.2	Elevated station	Nos.	11.0	26.68	293.5
4.1.3	At grade station	Nos.	0.0	-	-
4.2	Tunnel Ventilation	R Km	15.05	3.19	48.0
5.0	**Depot-cum-Workshop**		2.0		**205.66**
5.1	Modipuram Depot				
5.1.1	Civil works	Nos.	1.0	84.63	84.6
5.1.2	Plant and Machinery	Nos.	1.0	76.98	77.0
5.2	Duhai Depot				
5.2.1	Civil works	Nos.	1.0	24.07	24.1
5.2.2	Plant and Machinery	Nos.	1.0	19.98	20.0
6.0	**Permanent Way**				**634.04**
6.1	Ballastless track for elevated & underground alignment	R KM	93.0	6.48	602.5
6.2	Ballasted/Embedded track for at grade allignment (for Depot incl. 1.4 km for non electrical lines)	R KM	11.25	2.8	31.5
7.0	**Traction & Power Supply incl. OHE, ASS etc.**				**758.10**
7.1	Under Ground Section	R KM	31.1	8.70	270.7
7.2	Elevated & At Grade Section	R KM	71.7	6.80	487.4
8.0	**Signalling and Telecom. (incl. Depot lines)**				**755.33**
8.1	Signalling	R KM	103.1	6.34	653.3
8.2	Telecom.	No. of Stations	17.0	6	102.0
9.0	**Automatic fare collection**				**79.90**
9.1	Ticketed Stations	No. of Stations	17.0	4.7	79.9
10.0	**R & R**				**52.12**

Item	Description	Units	Quantity	Rate	Total
				Rs. Crore/ per Unit	Rs. Crore
10.1	R & R incl. Hutments and road restoration etc	R KM	104.2	0.5	52.1
11.0	**Misc. Works**				**197.74**
11.1	Utilities Relocation	R KM	104.2	0.5	52.1
11.2	Misc. civil works such as median, road signages	R KM	104.2	0.5	52.1
11.3	Barracks for Security Staff including security equipments	Nos.	17.0	0.5	8.5
11.4	Staff Quarters for O&M	Nos.	17.0	5	85.0
12.0	**Rolling Stock**				**1764.00**
12.1	EMU Coaches	Nos.	168	10.5	1,764.0
13.0	**Miscellaneous Items**				**127.15**
13.1	Training	Nos.	1	10.0	10.0
13.2	Spares	%	2.00%	3,357.3	67.1
13.3	Testing and Commissioning Costs	Nos.	1	50.0	50.0
14.0	**Total**				
14.1	Total (Including Land Cost)	Sum (1 to 13)			**15,128.8**
14.2	Total (Excluding Land Cost)	Item 14.1 Less 1			13,472.0
14.3	General Charges incl. Design charge	% of 14.2	13,472	5%	673.6
14.4	Contingency	14.1+14.3	15,802	5%	790.1
	Estimated Construction Cost on Year 2011 Basis (Excluding Land)				**14,935.72**
	Estimated Construction Cost on Year 2011 Basis				**16,592.47**

Base capital cost with taxes and duties is given below.

Sr. No.	Components	Amount in Rs. Million
1	Land	16,567.50
2	Base Construction Cost (excl. land cost & General Charges and Contingency)	134,720.03
3	**Total Base Project Cost**	**151,287.53**
4	Central Taxes	**14,265.93**
a	Customs Duty	9,211.20
b	Excise Duty	5,054.73
5	Cost including Central Taxes (3+4a+4b)	165,553.46
6	State Tax	**8,335.37**

Sr. No.	Components	Amount in Rs. Million
a	Value Added Tax	8,335.37
7	Cost including State Tax (5+6a)	173,888.83
8	General Charges @5% on (7 -1)	7,866.07
9	Contingency @5% on (1+7+8)	9,087.74
	Total Cost (incl. taxes excl. IDC)	**190,842.64**

0.27. Operation & Maintenance Cost Estimation

The operations and maintenance cost of RRTS Delhi Meerut would consist of the following:

a) Maintenance Cost including spare parts & consumables
b) Manpower Cost
c) Energy Cost

Maintenance Expenditure

Annual maintenance cost is provided for repair and maintenance of the facilities developed and spares parts, consumables required for the Project during the life span of the Project. The cost of such material which is consumed annually depends on a lot of factors such as the design of the equipment, the intensity of usage, the maintenance philosophy, the manufacturer's recommendations, renewal plans etc. The cost has been adopted based on experience in similar projects in India.

For this purpose maintenance cost has been taken at 0.80% of total capital cost of civil structure and system. The estimated maintenance cost for the first full year of operated (2018) is at Rs. 1,771 Million. Base annual maintenance costs (Rs. 1,259 Million) have been escalated for inflation at the rate of 5% year on year basis from 2011. Further, incremental maintenance cost for additional investments proposed during the project life has also been considered at the same rate as above. Year wise annual maintenance cost is set out below.

Sr. No.	Year	Annual Maintenance Cost
		Rs. Million / Year
1	2018	1,771
2	2021	2,060
3	2031	3,486
4	2041	6,145

Energy cost

Estimation of energy consumption for RRTS has been worked for following:

- Traction Consumption and Cost for the Route
- Traction Consumption and Cost for Depots (Modipuram & Duhai)
- Auxiliary Power Consumption and Cost for Stations
- Auxiliary Power Consumption and Cost for Depots (Modipuram & Duhai)

Sr. No.	Description	2018	2021	2031	2041
		Rs. Million			
1	Traction Cost	1187.0	1219.9	1780.5	1829.9
2	Traction Cost – Modipuram Depot	2.3	2.3	3.5	3.5
3	Traction Cost – Duhai Depot	1.1	1.1	1.6	1.6
4	Auxiliary power for Stations	739.8	804.7	947.6	1029.9
5	Auxiliary power - Depots	95.0	95.0	118.70	118.70
	Total Energy Cost	**2025.2**	**2123**	**2851.9**	**2983.6**

Manpower cost

The manpower cost has been determined by broadly determining staff requirement for the project and related salary and expenses.

Based on above, total O&M cost estimates are as under.

Sr. No.	Year	Manpower Cost
		Rs. Million / Year
1	2018	1,647
2	2021	2,282
3	2031	5,962
4	2041	15,575

Total O&M

Sr. No.	Year	Maintenance Cost	Energy Cost	Manpower Cost	Total
		Rs. Million			
1	2017	872	1,251	789	2,911
2	2018	1,771	2,491	1,647	5,909
3	2019	1,859	2,565	1,779	6,204
4	2020	1,952	2,642	1,921	6,516
5	2021	2,060	2,853	2,282	7,196
6	2022	2,195	2,939	2,465	7,598
7	2023	2,305	3,027	2,662	7,994
8	2024	2,420	3,118	2,875	8,413
9	2025	2,541	3,211	3,105	8,857
10	2026	2,668	3,308	3,689	9,664
11	2027	2,801	3,407	3,984	10,192
12	2028	2,941	3,509	4,303	10,753
13	2029	3,088	3,614	4,647	11,349
14	2030	3,243	3,723	5,019	11,984
15	2031	3,486	5,151	5,962	14,598
16	2032	3,914	5,305	6,439	15,659
17	2033	4,110	5,464	6,954	16,529
18	2034	4,316	5,628	7,510	17,455
19	2035	4,532	5,797	8,111	18,440
20	2036	4,758	5,971	9,636	20,365
21	2037	4,996	6,150	10,407	21,553

Sr. No.	Year	Maintenance Cost	Energy Cost	Manpower Cost	Total
		Rs. Million			
22	2038	5,246	6,335	11,240	22,820
23	2039	5,508	6,525	12,139	24,172
24	2040	5,783	6,721	13,110	25,614
25	2041	6,145	7,242	15,575	28,961
26	2042	6,680	7,459	16,821	30,960
27	2043	7,014	7,683	18,166	32,863
28	2044	7,365	7,913	19,620	34,898
29	2045	7,733	8,151	21,189	37,073
30	2046	8,120	8,395	25,173	41,688

0.28. Project Structuring and Viability

State governments have taken an aggressive stand in implementing similar transport infrastructure projects and such stand has been very well supported by the Central Government in pushing through these projects either by way of necessary legislation, land acquisition, equity commitments.

We understand that NCRPB has been instrumental in signing of MoUs with various states government, besides Ministry of Urban Development, Govt. of India (MoUD) and Ministry of Railways for making equity contribution to the RRTS project. Further, equity contributions are expected to be made in a company referred to as NCR Transport Company or say ("NCRTC") for the purpose of this report.

NCRTC is expected to be the holding company of all RRTS project and to our understanding to have an initial corpus of Rs. 100 crores shared in the following manner:

Sl. No.	Name of the Entity	Percentage (%)
1.	MoUD, Govt. of India + NCRPB	25
2.	Ministry of Railways + Govt. of India	25
3.	Govt. of National Territory of Delhi	12.5
4.	State Govt. of Uttar Pradesh	12.5
5.	State Govt. of Haryana	12.5
6.	State Govt. of Rajasthan	12.5
	Total	**100**

NCRTC SPV for Delhi- Meerut Structure

Each of the RRTS project can be developed through subsidiary of NCRTC where respective holding amongst state governments could be split based on project specific details. Therefore potential equity contributions could be as set out below:

Equity Contribution Structure of Delhi – Ghaziabad - Meerut Project

Sl. No.	Name of Entity	Percentage (%)
1.	MoUD, Govt. of India + NCRPB	25
2.	Ministry of Railways + Govt. of India	25
3.	Govt. of National Territory of Delhi, State	50

	Govt. of Uttar Pradesh	
	Total	**100**

The contribution of GNCTD and Govt of UP could be split potentially made with following options:

a) In terms of route length
b) In terms of investment
c) In terms of shareholding in the holding company

Role of Lenders

Multi-lateral funding agencies such as JICA, World Bank and ADB have shown keen interest in funding these projects. These projects are typically backed by central government guarantees towards repayment. Typically the loan repayment could be done from the project company, however, the exchange rate risk is taken on by the central government in such debt financing deals.

The project of this size would require, ideally soft loan from a multi lateral institution on attractive terms such as a loan paid of 20 to 30 years with interest rate less than 2%. We believe that the project could obtain atleast 40% of the construction cost at soft loan from suitable multi lateral funding agency e.g. World Bank, JICA and ADB with exchange rate risk typically borne by Government of India.

Role of Private Sector

Private sector as the concessionaire have been fairly active in the Indian market in being part of these projects on reasonable commercial terms. Some of the projects have been successfully bid out using land banks provided as part of the project, such as Hyderabad Metro project. Other projects have used the distinction of basic infrastructure costs and rolling stock required for the project in order to enable the private sector participation, besides use of some commercial development.

DIMTS has carried out analysis for structuring the project under the PPP frame work, wherein the project can be developed under a suitable PPP frame work. The total life cycle investment in the project is Rs 196,679 Million.

Based on financial analysis undertaken private sector would be in a position to contribute 25-40% of the initial cost of construction, besides undertaking several other project responsibilities.

Role Division Between Private Sector and Government or say NCRTC

Based on technical analysis carried out, it is believed that the project element which could be split between government and private sector are set out in the table below:

Project Components – Government vs Private Sector

Sr. No	Project Components	Total	Government	Private Sector
		Rs. Million		
1	Land, R&R, Utility shifting & Misc. works	**19,066**	19,066	-

Sr. No	Project Components	Total	Government	Private Sector
		Rs. Million		
2	Civil works, Alignment and formation	**57,589**	57,589	-
3	Station Building	**23,936**	9,802	14,134
4	E&M Works	**7,455**	4,520	2,935
5	Depot-cum-Workshop	**2,057**	1,087	970
6	Permanent Way	**6,340**	6,340	-
7	Traction & Power Supply incl. OHE, ASS etc.	**7,581**	7,581	-
8	Signalling and Telecom.	**7,553**	-	7,553
9	Automatic fare collection	**799**	-	799
10	Rolling Stock	**17,640**	-	17,640
11	Miscellaneous Items	**1,271**	-	1,271
12	General Charges incl. Design charge	**6,736**	4,471	2,265
13	Contingency	**7,901**	5,523	2,378
	Total Base Construction Cost	**165,925**	**115,979**	**49,946**
	% of Initial Investment	**100%**	**69.90%**	**30.10%**
	% of Total Life Cycle Investment	**100%**	**58.97%**	**41.03%**

From the above analysis we suggest that about 70% of the initial construction cost would need to be contributed by the government or multilateral financial institutions. It would be prudent to, therefore split the project to deliver optimum project structuring wherein a government entity could raise fund from Financial Institutions and its own sources with about 30% of project cost from private sector investment.

Project Structure

The specific role of SPV which could be launched by NCRTC and the role of private sector based on analysis provided in the previous section is being setout in the following paragraphs.

It is proposed that the project implementation is taken by way of splitting the project in the following two SPVs:

a) RRTS Delhi-Meerut Infrastructure Limited (“DM Infraco”)
b) RRTS Delhi-Meerut Rolling stock Limited (“DM Rollco”)

Total Investment breakup (Capital cost including taxes, escalation, IDC and margin money)

Sr. No	Entities	Investment based on length		Contribution based on Initial Investment	
		%	Rs. Crore	%	Rs. Crore
	Investments by DM Infraco				
1	MoUD, Govt. of India +	7.37%	1,568	7.37%	1,568

Sr. No	Entities	Investment based on length		Contribution based on Initial Investment	
		%	Rs. Crore	%	Rs. Crore
	Investments by DM Infraco				
	NCRPB				
2	Ministry of Railways + Govt. of India	7.37%	1,568	7.37%	1,568
3	Govt. of National Territory of Delhi	1.70%	362	2.65%	564
4	State Govt. of Uttar Pradesh	13.04%	2,774	12.09%	2,571
	Total	**29.48%**	**6,271**	**29.48%**	**6,271**
	Soft Loan	**40.23%**	**8,559**	**40.23%**	**8,559**
	Investments by DM Rollco				
	Private Sector	**30.29%**	**6,444**	**30.29%**	**6,444**
	Total	**100.00%**	**21,274**	**100.00%**	**21,274**

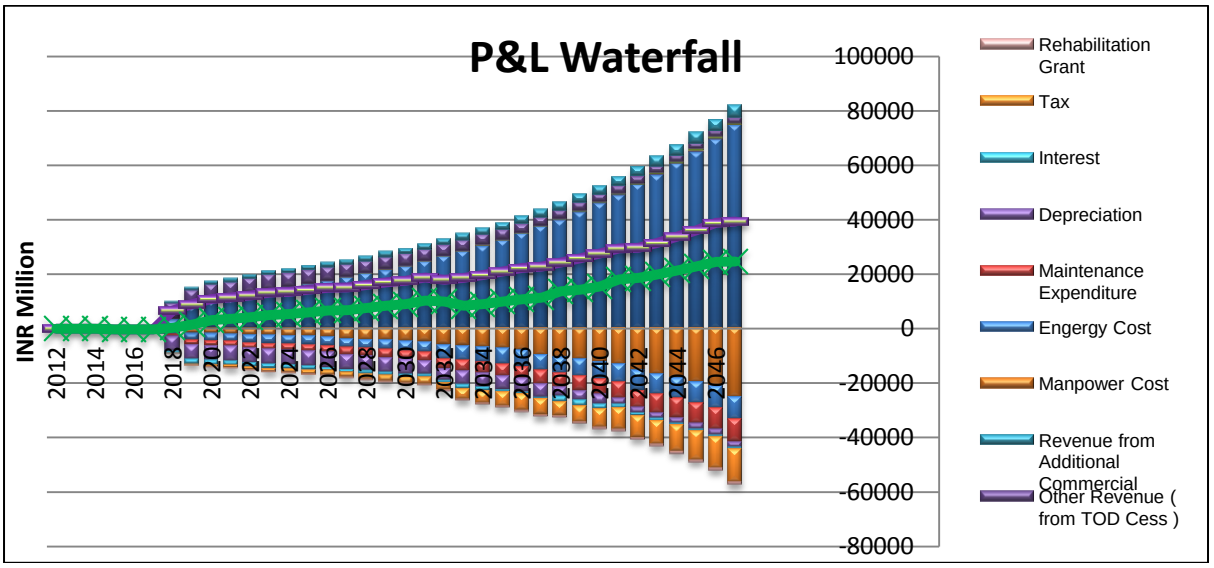
The aforesaid excludes the project funding required for additional investments in future as well replacement costs associated with the project. These costs shall be required to be incurred by the DM Rollco.

Profit and loss account

Profit and Loss statement synopsis for key years is shown below.

Sr. No.	Description	FY18	FY19	FY20	FY21	FY31	FY41	FY46
A	**Revenue**							
1	Fare box – Full Fare	6,736	8,306	9,218	10,230	21,008	41,986	59385
2	Fare box- Concessional Fare	1,740	2,146	2,381	2,642	5,426	10,845	15339
	Total Fare box revenue	**8,476**	**10,452**	**11,599**	**12,873**	**26,434**	**52,831**	**74724**
3	Revenue from rentals	45	55	59	63	102	167	213
4	Revenue from Property development	894	1,143	1,227	1,292	2,104	3,427	4374
5	Revenue from advertisement rights	85	105	116	129	264	528	747
6	TOD Cess	5,654	5,654	5,277	5,277	4,146	2,482	1921
	Total Revenue	***15,154***	***17,408***	***18,279***	***19,633***	***33,051***	***59,435***	***81979***
B	**Expenses**							
1	Maintenance Cost	1,771	1,859	1,952	2,060	3,486	6,145	8120
2	Manpower Cost	1,647	1,779	1,921	2,282	5,962	15,575	25173
3	Energy Cost	2,491	2,565	2,642	2,853	5,151	7,242	8395
4	Rehabilitation Grant	233	244	257	269	439	715	912
	Total Operating Expenses	***6,141***	***6,448***	***6,772***	***7,465***	***15,037***	***29,676***	***42600***
5	EBITDA	9,012	10,960	11,507	12,168	18013	29759	39379
6	Depreciation	5,318	5,318	5,318	5,342	4540	2041	2038

Sr. No.	Description	FY18	FY19	FY20	FY21	FY31	FY41	FY46
7	EBIT	3,694	5,642	6,189	6,826	13473	27718	37341
8	*Interest (long & short term)*	1,766	1,722	1,655	1,589	900	986	821
9	PBT	1,928	3,920	4,533	5,236	12573	26732	36520
10	*Income Tax*	386	784	907	1,048	2,567	8,080	11,780
11	**PAT**	**1,542**	**3,136**	**3,626**	**4,189**	**10,005**	**18,652**	**24,740**



Cash flow and return for the project

The estimation of the internal rate of return for the project is based on cash flow projected for the concession period for the project.

Sr. No.	Description	FY13	FY14	FY15	FY16	FY17	FY21	FY22	FY31	FY32	FY36	FY37	FY41	FY46
A	**Calculation of Project IRR**													
I	**Inflow (Rs. Million)**	-	(191)	(201)	(211)	391	4,189	5,012	10,005	8,422	11,362	13,771	18,652	24,740
1	PAT	-	-	-	-	902	1,589	1,566	900	1,438	611	1,985	986	821
2	Interest	-	-	-	-	5,318	5,342	5,416	4,540	4,902	4,902	3,475	2,041	2,038
3	Depreciation	**-**	**(191)**	**(201)**	**(211)**	**6,611**	**11,120**	**11,993**	**15,446**	**14,763**	**16,875**	**19,231**	**21,679**	**27,600**
	Total Inflow													
II	**Outflow**													
1	Capital Investment	(23,632)	(61,631)	(74,835)	(48,387)	(4,256)	(772)	(2,317)	(3,806)	(11,418)	(7,506)	(22,518)	(2,092)	-
2	IDC	-	-	407	1,445	838	-	-	-	-	-	-	-	-
	Total Outflow	**(23,632)**	**(61,631)**	**(74,428)**	**(46,943)**	**(3,417)**	**(772)**	**(2,317)**	**(3,806)**	**(11,418)**	**(7,506)**	**(22,518)**	**(2,092)**	**-**
	Net Flow	**(23,632)**	**(61,823)**	**(74,629)**	**(47,154)**	**3,194**	**10,348**	**9,676**	**11,640**	**3,345**	**9,369**	**(3,287)**	**19,587**	**27,600**

Sr. No.	Description	FY13	FY14	FY15	FY16	FY17	FY21	FY22	FY31	FY32	FY36	FY37	FY41	FY46
	Project IRR (post -tax)	**4.25%**												

Sr. No.	Description	FY13	FY14	FY15	FY16	FY17	FY21	FY22	FY31	FY32	FY36	FY37	FY41	FY46
A	**Equity IRR Calculation**													
	Inflow (Rs. Million)													
1	PAT	-	(191)	(201)	(211)	391	4,189	5,012	10,005	8,422	11,362	13,771	18,652	24,740
2	Interest	-	-	-	-	5,318	5,342	5,416	4,540	4,902	4,902	3,475	2,041	2,038
3	Repayment	-	-	-	-	2,140	4,280	6,751	4,280	8,816	4,280	6,676	4,537	-
	Total Inflow	**-**	**(191)**	**(201)**	**(211)**	**7,849**	**13,811**	**17,178**	**18,825**	**22,140**	**20,544**	**23,922**	**25,230**	**26,778**
1	*Equity Contribution*	**(16,564)**	**(43,197)**	**(4,676)**	**-**	**(0)**	**(154)**	**(463)**	**(761)**	**(2,284)**	**(1,501)**	**(4,504)**	**(418)**	**-**
	Net flow	**(16,564)**	**(43,389)**	**(4,87)**	**(211)**	**7,849**	**13,656**	**16,715**	**18,064**	**19,857**	**19,042**	**19,419**	**24,812**	**26,778**
	Equity IRR (DMRollco)	**15.85 %**												

Debt service and DSCR

The debt servicing of the soft loan can be under taken from the development cess on TOD levied on sale of built up area as described in the Revenue estimation chapter.

The table below provides the Net Present Value (@10% discount factor) of the revenues generated from TOD cess and principal and interest repayment of the soft loan from the multilateral agencies.

Sr. No.	Description	Amount (INR Million)	Remarks
		NPV@10 %	
A	**Revenue from cess on TOD**		
1	During Construction	5,793	The cess collected during construction phase can be used to fund the equity contribution by the Govt for the project
2	During Operations	**25,087**	The cess collected during the operations period can be utilized for servicing the soft loan
B	Debt Servicing Requirement		
1	Principal Repayment	**19,631**	
2	Interest Payment	**5,106**	
	Total Debt Servicing	**24,737**	
	Surplus after Debt servicing	**350**	**Surplus funds after debt servicing may be distributed among the shareholders.**

The Average Debt service coverage ratio for the project is 2.96, with minimum DSCR observed at 1.43.

Total Lifecycle Investment

The total lifecycle cost investment by the government and private sector partner in terms of 2011 price levels is presented below:

Total lifecycle investment by Government vis a vis private sector partner at 2011 price levels

Sr. No	Project Components	Total	Government	Private Sector
		Rs. Million		
1	Land, R&R, Utility shifting & Misc. works	**19,066**	19,066	-
2	Civil works, Alignment and formation	**57,589**	57,589	-
3	Station Building	**23,936**	9,802	14,134
4	E&M Works	**7,455**	4,520	2,935
5	Depot-cum-Workshop	**2,057**	1,087	970
6	Permanent Way	**6,340**	6,340	-
7	Traction & Power Supply incl. OHE, ASS etc.	**7,581**	7,581	-
8	Signalling and Telecom.	**7,553**	-	7,553
9	Automatic fare collection	**799**	-	799
10	Rolling Stock	**17,640**	-	17,640
11	Miscellaneous Items	**1,271**	-	1,271
12	General Charges incl. Design charge	**6,736**	4,471	2,265
13	Contingency	**7,901**	5,523	2,378
14	**Total Base Construction Cost**	**165,925**	**115,979**	**49,946**
15	**Percentage Distribution**	**100%**	**69.90%**	**30.10%**
16	IDC & Margin Money	3,069		3,069
17	Future Capital Investments	13,763		13,763
18	Replacement Cost	13,922		13,922
19	**Total Life Cycle Investment**	**196,679**	**115,979**	**80,700**
20	**Percentage Distribution**	**100%**	**59%**	**41%**

0.29. Economic Internal Rate of Return (EIRR)

The benefits of project include fuel cost savings, time savings due to increased speed, savings in highway construction costs, capital cost saving of vehicles and environmental benefits. These are added together to get the total savings. These benefits are equated with economic cost of the project during life cycle to determine Economic IRR. The net cash flow statements are presented in table below**.** The rate of return considered desirable for the transport infrastructure project in India is 12

percent. As EIRR of proposed RRTS facility is 24.10 %, which is above 12 percent cut-off rate, the project is economically viable.

0.30. Recommendations and Way Forward

Financial Analysis of DMInfraco and DMRollco have been made in order to ensure that there are no hidden surprises at the time of bidding the project.

It would be prudent for NCRPB to select one PPP structure for all RRTS project and develop a bidding criteria which can stand the test of time as well as variability of various RRTS Project.

It is proposed that DIMInfraco will carry 10% stake in DMInfraco thus, 10% stake in DMRollco by DMInfraco assumes great signification since DMInfraco will bid out the project, based on the valuation of equity of DMRollco. This would be by way of positive or negative valuation for nominal 10% of DMRollco share by the Concessionaire who shall have the controlling stake in the DMRollco.

It may be noted that the project have been further stress tested to understand if the project can sustain marked borrowing at 10-12% and the result for project are acceptable.

To move forward on the project, following actions could be taken immediately

(i) Formulation of DMInfraco with equity share holding with percentage as suggested in the report
(ii) Setting up of DMRollco with minimum capital charges are required in terms of company law
(iii) Commencement of negotiation with financial institution and Government of India for obtaining soft loan.
(iv) Selection of suitable transaction advisory:
  a) Commencement dialogue with India
  b) Commencement with bidding process
(v) Inviting state governments to obtain necessary equity stake in the Infraco.
(vi) Declaration of Transit Oriented Development zones
(vii) Preparation of Development Plans based on ToD Areas identified by this report within a timeframe say 3 months of release of this report
(viii) Legislation for collection of cess from ToD areas
(ix) Land acquisition where required for the project infrastructure area

1. INTRODUCTION

1.1 National Capital Region

National Capital Region ("NCR") is a multi-state region with Nation Capital as its centre. It covers an area of 33,578 sq km spreading over four constituent States of Delhi, Haryana, Rajasthan & Uttar Pradesh.

The National Capital Region Planning Board was constituted under the National Capital Region Planning Board Act, 1985 with the concurrence of the State legislatures of the participating States of Haryana, Uttar Pradesh and Rajasthan, (Delhi being a Union Territory at that time). It has the mandate for preparation of a Plan for the development of the National Capital Region and for coordinating and monitoring the implementation of such plan and for evolving the harmonized policies for the control of land uses and development of infrastructure in the National Capital Region comprises an area of 33,578 square kilometers and covers eight districts of Haryana, five districts of Uttar Pradesh, one district of Rajasthan and the entire National Capital Territory of Delhi. The National Capital Region also has five Counter-magnet Areas outside the Region, namely, Hissar (Haryana), Bareilly (Uttar Pradesh), Kota (Rajasthan), Patiala (Punjab) and Gwalior (Madhya Pradesh).

NCR Planning Board prepared a Regional Plan with the perspective for year 2021 for the National Capital Region which was notified on 17.9.2005 for implementation. The Plan aims at promoting growth and balanced development of the National Capital Region. In this endeavor the effort is to harness the spread of the developmental impulse and agglomeration economies generated by Delhi. The above objective is sought to be achieved through:

i.) By providing suitable economic base for future growth and by identification and development of regional settlements capable of absorbing the economic development impulse of Delhi.
ii.) To provide efficient and economic rail and road based transportation networks (including mass transport systems) well integrated with the land use patterns.
iii.) To minimize the adverse environmental impact that may occur in the process of development of the National Capital Region.
iv.) To develop selected urban settlements with urban infrastructural facilities such as transport, power, communication, drinking water, sewerage, drainage etc. comparable with Delhi.
v.) To provide a rational land use pattern in order to protect and preserve good agricultural land and utilize unproductive land for urban uses.
vi.) To promote sustainable development in the Region to improve quality of life.
vii.) To improve the efficiency of existing methods and adopt innovative methods of resource mobilization, and facilitate, attract and guide private investment in desired direction.

National Capital Region (NCR) is a unique example for inter-state regional development planning for a region with National Capital at its core. It is one of the largest National Capital Region of the World and constitutes about 1.60% of the country's land area. NCR is the home of 371 lakhs people living in 108 towns of which 17 are class I cities and more than 7500 rural settlements.

The four constituent Sub-Regions of NCR are given below:

1) The Haryana Sub-Region comprising of nine districts, that is, Faridabad, Gurgaon, Mewat, Rohtak, Sonepat, Rewari, Jhajjhar, Panipat and Palwal together constituting about 40% (13,413 sq. kms.) of the Region;
2) The Uttar Pradesh Sub-Region comprising of five districts, that is, Meerut, Ghaziabad, Gautam Budha Nagar, Bulandshahr, and Baghpat together constituting about 32% (10,853 sq. kms.) of the Region;
3) The Rajasthan Sub-Region comprising of Alwar district constituting about 23% (7,829 sq. kms.) of the Region ; &
4) The NCT of Delhi constituting about 5% (1,483 sq. kms.) of the Region.

Figure 1-1 : National Capital Region

The population of NCR is projected to be 641.38 lakhs by 2021. Based on the projections & policies given in the Regional Plan-2021 for NCR, it is expected that the population of NCT-Delhi Sub-region would be 225 lakhs by 2021 and 163.50 lakhs, 49.38 lakhs & 203.50 lakhs for Haryana, Rajasthan Sub-region & Uttar Pradesh Sub-regions respectively.

The thrust areas of the Regional Plan – 2021 for NCR mainly includes:

1. Lays down Land Uses at the Regional level in terms of a harmonious pattern emerging from a careful examination of natural features including susceptibility to natural disasters and socio-economic activities
2. Proposes Development of Metro and Regional Centres as powerful growth nodes to attract major activities
3. Provide regional transport linkages and Mass Commuter System
4. Construction of peripheral expressways and orbital rail corridor around Delhi
5. Development of core urban infrastructure (transport, power, water supply, sewerage, drainage) in NCR towns
6. Development of the region's economy through Model Industrial Estates, Special Economic Zones outside NCT-Delhi

The Regional Plan-2021 for NCR has proposed a six tier Settlement System consisting of Metro Centres, Regional Centres, Sub-Regional Centres, Service Centres, Central Villages and Basic Villages. The urban agglomerates selected consist of 7 Metro Centres/ Complexes outside NCT of Delhi with a population of one million and above consisting of Gurgaon-Manesar, Faridabad-Ballabhgarh, Ghaziabad-Loni, Noida, Greater Noida, Meerut and Sonepat-Kundli; and 11 Regional Centres/Complexes namely Bahadurgarh, Panipat, Rohtak, Palwal, Rewari-

Dharuhera-Bawal, Hapur-Pilakhua, Bulandshahr-Khurja, Baghpat-Baraut, Alwar, Greater Bhiwadi & Shahjahanpur-Neemrana-Behror.

Delhi has a limited area of 1482 sq km out of which approximately half the area is already urbanized. As per IRS IC LISS III Satellite Data (1999) the developed area in Delhi was approximately 47.31 percent where as total urbanisable area is only 65.94 percent. In the last decade, Delhi has seen substantial development (like, development at Dwarka, Rohini, Jasola) and there is limited space available for further land use growth in Delhi.

1.2 Background of the Study

As part of the initiative of NCRPB, it has prepared a Transport Plan as part of the 'NCR Regional Plan - 2021' with an objective to "promote and support the economic development of the region and relieve the Capital of excessive pressure on the infrastructure including traffic congestion. It is to provide accessibility to all parts of the region and discourage the transit of passengers and goods through the core area of NCT – Delhi by providing bypasses and there by opening areas for economic development of the rest of the region". The Transport Plan 2031 emphasizes the need for development of settlements outside NCT – Delhi and providing inter-connection between Delhi and settlements, the 'NCR Transport Plan 2031' has proposed to:

- Develop activities keeping in view rail and road linkages in Central NCR having better accessibility and at the same time relieving pressure on the existing transport routes converging at NCT-Delhi.

- Unrestricted movement of buses, taxis and auto-rickshaws within NCR. Focus on certain inter-state issues (e.g. land acquisition) for workable coordination and evolve an institutional mechanism on priority basis to encourage private participation.

- Execution without further delays of the Regional Plan-2001 proposals of Integrated Mass Rapid Transport System (MRTS), Regional Rapid Transport System (RRTS), Expressways and Bypasses.

New Delhi has an impressive public transport system with about 190 km of Metro system supported by a fleet of more than 6000 buses which is expected to increase to 10,000 by 2012. The Delhi Metro network is also expected to double over the next five years to more than 400kms.

NCRPB has developed an NCR Plan 2031 wherein eight Regional Rapid Transit corridors (RRTS) (with an average speed of 200 km/hr) have been proposed for development to achieve fast and seamless connectivity for the satellite towns with Delhi. Out of the aforesaid eight corridors, three RRTS corridors have been chosen for implementation initially viz.

- Panipat-Sonepat-Delhi (Length-89 km)
- Meerut-Ghaziabad-Delhi (length 67 km) and
- Delhi-Alwar (Length 158 km).

To undertake the development of these projects relevant studies have been commissioned and these have reached advance stages. Development of Detailed Project Reports (DPR's) for two of the above mentioned corridors is being undertaken by Delhi Integrated Multi Modal Transit Systems (DIMTS), a joint venture of Govt. of Delhi and IDFC (a financial institution promoted by Government of India).

1.3 Vision of RRTS

The vision of developing Rapid Rail Transit System (RRTS) is to:

- An optimized hi-speed link to suit transport demand requirements
- A high quality transport system having predominantly seated accommodation and good comfort level for passengers
- Broad gauge track for wider coaches for interoperability with existing railway networks
- Coaches must meet standard Indian structure profile
- Optimized locations of stations for ease of access to commuters and to serve maximum volume of ridership
- Optimize route and ridership needs so as to achieve good operating speeds
- Optimize the number of stops in concordance with the desired operating speed
- The operating pattern may include both non-stop and stopping at all stations journeys. The non-stop journey to be in the order of 45-50 minutes for the RRTS corridor
- The Delhi terminus may be located for interchange with the existing Delhi Metro network or any other separate continuing link with other alignments in the RRTS
- Interchange with other MRTS corridors including the development of feeder systems to other MRTS corridors

The project corridor has the potential to serve a substantial volume and diverse commuter spectrum, while connecting the major cities and towns along the project stretch. The proposed RRTS system is to be designed as a controlled access system with a Design Speed in range of 180-200 km/hr. It has been suggested by NCRPB that the corridor is expected to serve the commuter traffic at comparatively higher speeds than that of the existing MRTS systems such as Delhi Metro. The RRTS as suggested is to be designed on the Indian Railways Broad Gauge system in order to accommodate substantial commuter traffic.

1.4 Scope of Work, milestones achieved and contents of the report

1.4.1. Scope of work

DIMTS has been awarded the work for preparation of feasibility report followed by Detailed Project Report for the proposed Delhi -Ghaziabad -Meerut RRTS corridor by NCRPB. As a part of current milestone, the following deliverables/ reports are being submitted:

I.) This **Feasibility Report** covers following aspects of the study:

a) Financial Analysis of the study covering the following:

i.) Detailed Capital and operational cost for the project.

ii.) Proposed fare structure and revenue generation and its comparison with existing systems specific to urban EMU.

iii.) Financial viability analysis including details of the financial model developed.

iv.) Various Public Private Partnership (PPP) alternatives and suggested alternative best suited for the system.

v.) Identifying sources of funding for the project.

vi.) Financial plan – analyzing the revenues and costs (capital costs and operational costs), identification of debt servicing capability and operational capability

vii.) Cost Benefit Analysis of carrying the same travel demand through RRTS vis-a-vis other modes of transport and infrastructure improvement.

viii.) Study of Transit Oriented Development (TOD) and suggestions for ways by which TOD can be utilized to generate funds that can be used for part funding of the project.

b) The feasibility report integrates all the previous reports submitted by DIMTS as per agreed milestones by providing a summary of all these reports. The reports earlier submitted and summarized in the Feasibility report are as follows:

i.) Travel Demand Forecast Report

ii.) Existing Condition Analysis Report

iii.) Alignment Options and Proposed Alignment Report

iv.) Engineering and Operations report being submitted along with Feasibility Report

v.) Topographical Survey Report Vol 1: Main Report being submitted along with the Feasibility Report

vi.) Topographical Survey Report Vol II: Proposed Plan and Profile being submitted along with the Feasibility Report

vii.) Geotechnical Report being submitted along with the Feasibility Report

1.4.2. Structure of Feasibility Report

This report is laid out in twelve (12) sections; a summary of each section is detailed below:

1. Chapter 1: Introduction: The current section provides the background and objectives of the project, scope of work, deliverables and milestones achieved under the project and report structure.

2. Chapter 2: Approach and Methodology - This section provides the overall approach and methodology of Financial Analysis / Business Plan.

3. Chapter 3: Recommendations from Travel Demand Forecast study - This section provides a summary of the travel demand forecast study conducted under the assignment along with estimated ridership figures.

4. Chapter 4 – Review of present alignment:- This section provides the summary of Existing Condition Analysis report submitted earlier as a part of this Assignment

5. Chapter 5: Proposed Alignment - This section provides an overview of the methodology followed to finalize proposed alignment and summarizes the Proposed Alignment Report submitted earlier as a part of this assignment. The chapter also describes the station locations along the corridor alongwith the Transit Oriented Development strategy and requirement for the project.

6. Chapter 6: Key Inputs from Engineering and Operations Study - This section provides an overview of the detailed engineering study conducted for the establishing the technical feasibility of the project. This chapter summarizes the key technical parameters related to requirement of rolling stock, signaling systems, civil works, station design, power systems that have been finalized for the project.

7. Chapter 7: This chapter provides details of assumption and inputs taken for the financial model.

8. Chapter 8: This chapter provides details of revenue estimates from farebox and other revenue sources identified for the project.

9. Chapter 9: Capital cost estimation - This section estimates the capital cost for the project and provides information on the basis for estimation of capital cost.

10. Chapter 10:- Operations and Maintenance cost estimation: This chapter details the O&M cost estimation for the project.

11. Chapter 11: Project Structuring and Viability - This section provides a detailed analysis of the financial feasibility of the project under various input scenarios and assumptions. This chapter calculates Internal Rate of Return for the project. The chapter also provides various options of structuring the project including PPP alternatives. Also the chapter gives an overview of project structures and funding mechanisms of similar urban transport rail based PPP projects across the country. The section also tries to identify the potential funding sources for the project. The role of government support in terms of administrative support, policy interventions for the project has also been explained.

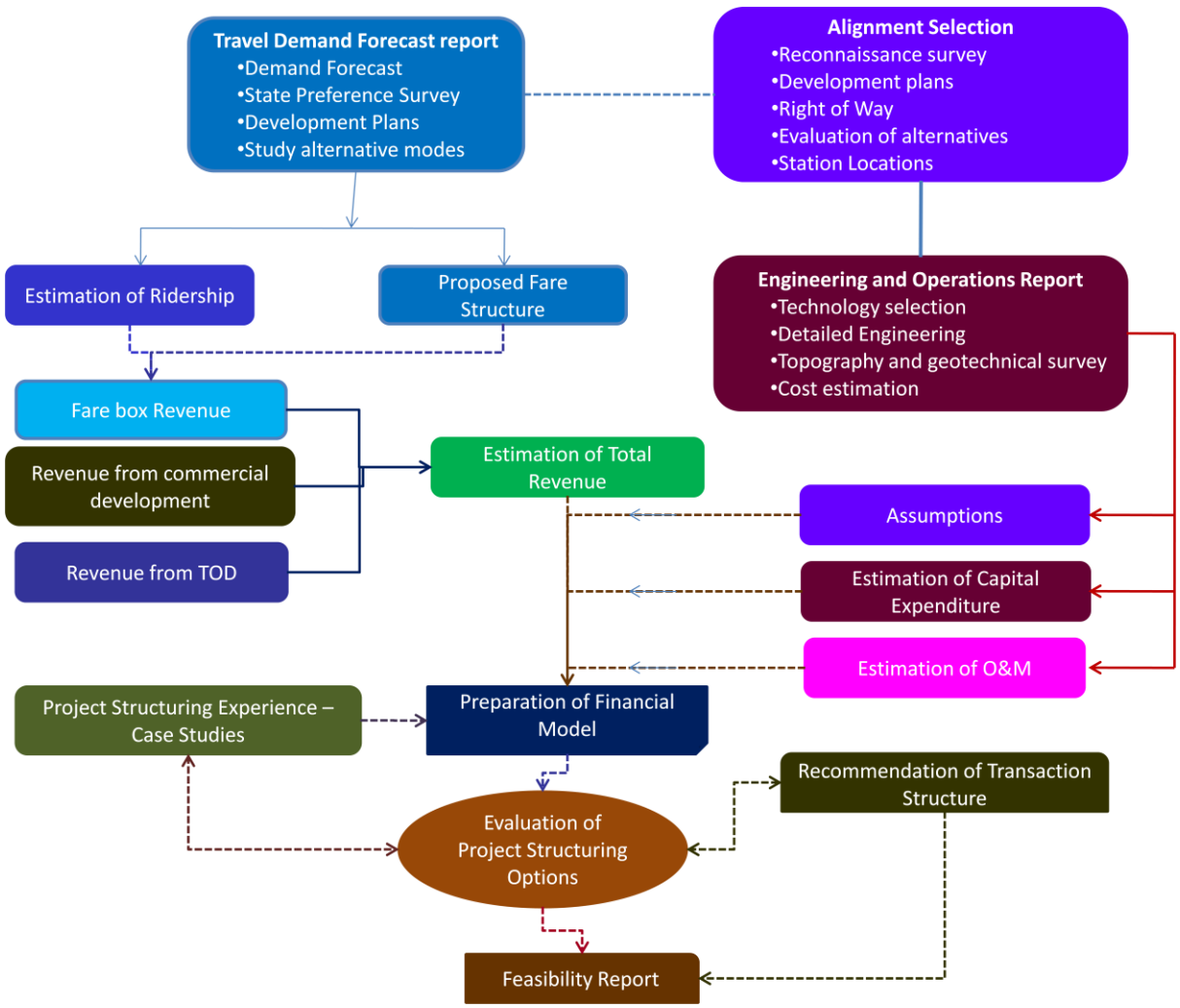
12. Chapter 12: This chapter details the economic viability of the project calculating the EIRR for the project.

2. APPROACH AND METHODOLOGY

2.1 Overall Approach for business plan

The figure below depicts the overall approach for preparation of the Feasibility Report for the RRTS Delhi- Ghaziabad -Meerut corridor.

Figure 2-1 : Approach & Methodology



2.1.1. Development of financial model

DIMTS has developed a detailed financial model that integrates the financial inputs related to investments and estimates of revenue from ridership and other sources based on the Engineering and Operations Report and Travel Demand Forecast Report undertaken as a part of this assignment. Based on estimates from the aforesaid traffic study, estimates of ridership over the horizon period of 30 years have been prepared. Suitable fare structure has been prepared enabling calculation of the potential revenues from passengers. Further revenue from commercial development,

an essential part of the station complex and from development of Transit Oriented Development has been assessed and incorporated in the revenue projections. The financial model has been used to develop various scenarios related to variations in capital cost, phasing of expenditure, sensitivity related to fare structure etc.

2.1.2. Project structuring and viability

DIMTS has developed suitable options on project structure and based on such project structure identified the project viability covering the following:

- Financial projections and assessment of financial viability.
- Identifying the possible sources of funding for the project along with options for phasing of the project.
- Identifying viability enhancing measures required such as capital grants, guarantees, and/or potential revenue from commercial development and TOD.
- Potential PPP structure that can be explored for encouraging the private investment in the project.
- Policy level interventions.

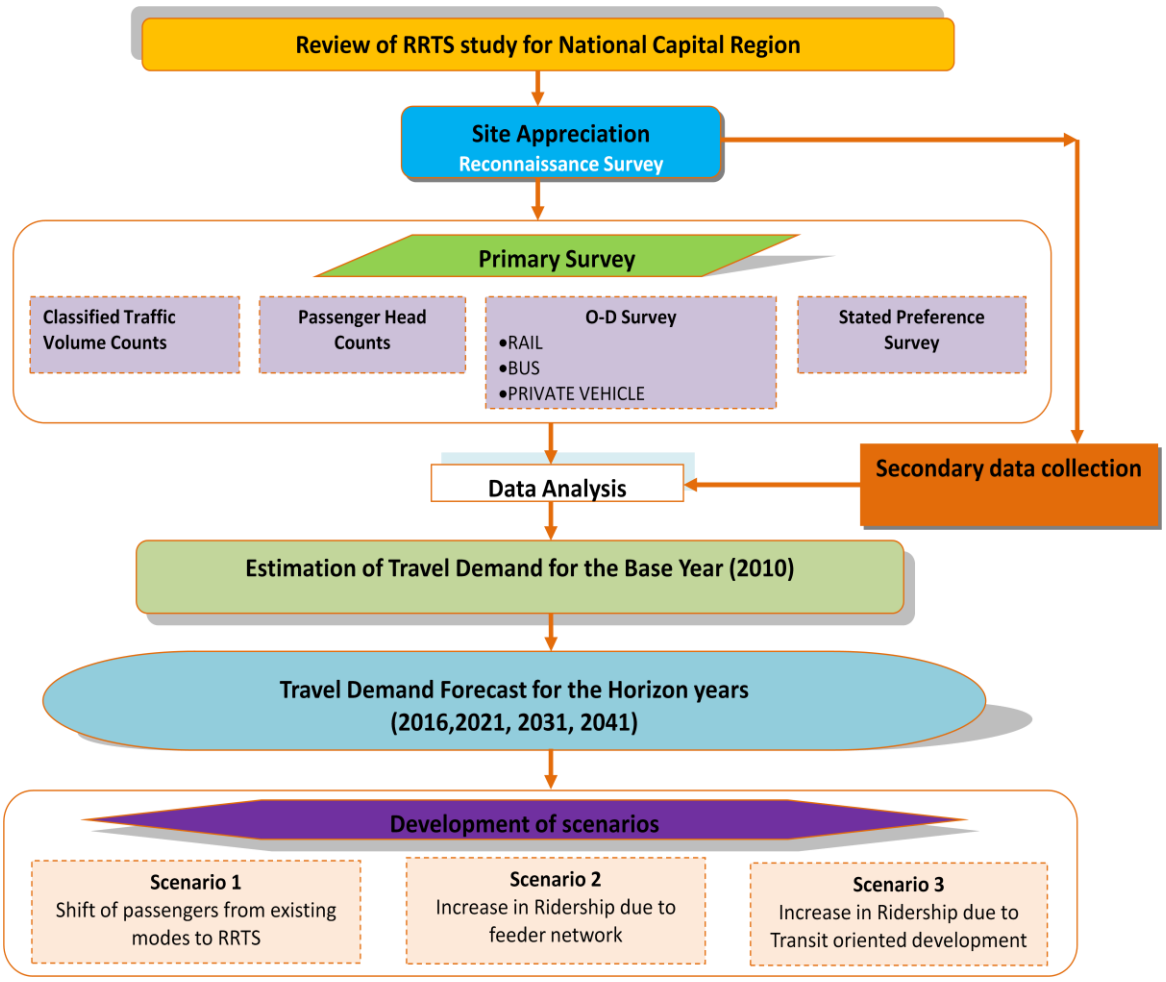
3. RECOMMENDATIONS FROM TRAVEL DEMAND FORECAST STUDY

3.1 Detailed Travel Demand Forecast Study

The Travel Demand Forecast Study has been conducted as a part of the preparation of a Feasibility Report followed by Detailed Project Report for development of Regional Rapid Transit System (RRTS) for Delhi – Ghaziabad – Meerut Corridor for a rail based transportation system integrated with multi modal transport infrastructure for NCR. This chapter presents the synopsis of the Travel Demand Forecast Study conducted. A detailed report on the Demand Forecast Study has already been submitted and may be referred to for any further details required.

The study methodology adopted for transport demand forecast is presented in Figure below.

Figure 3-1 : Study Methodology for Transport Demand Forecast



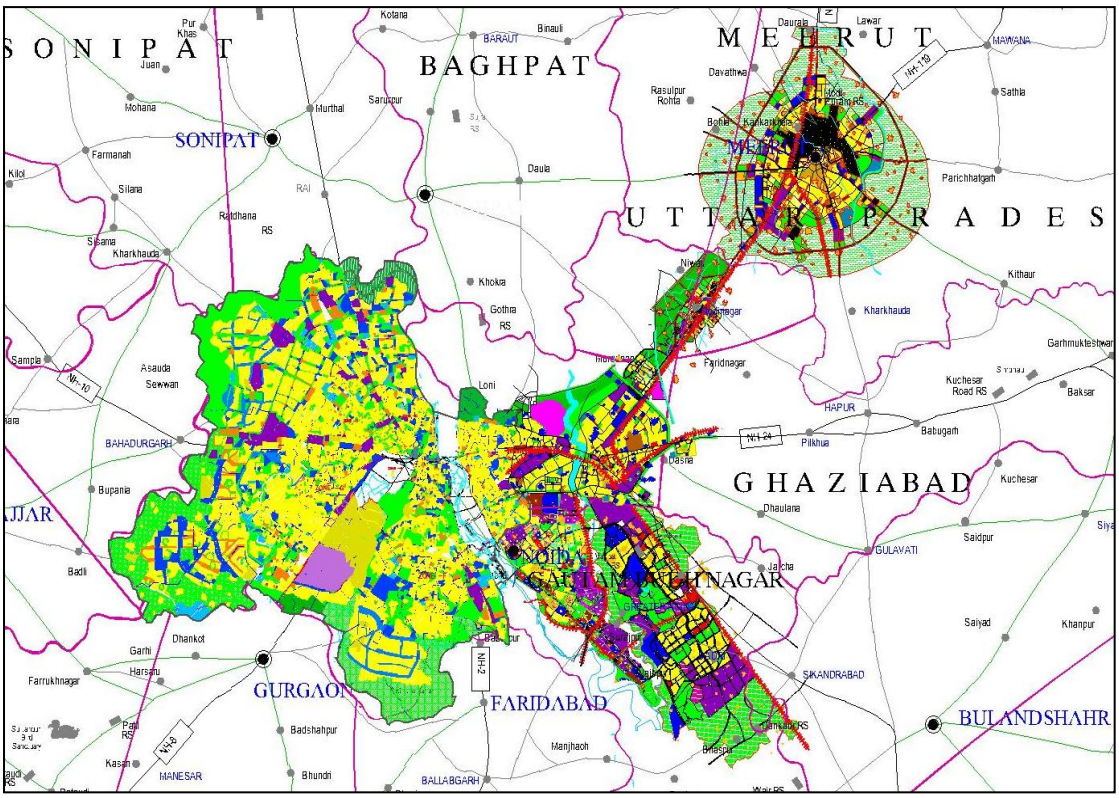
3.2 Existing Connectivity on the Project Corridor

The Delhi – Ghaziabad – Meerut project corridor is in the states of Delhi and Uttar Pradesh. The cities of Delhi and Meerut are connected through NH-24 and NH-58. NH-58 is the main and most used road link between Meerut and Delhi and carries most of the road traffic between NCT and Meerut/ Hardwar/ Dehradun.

The following State Highways are at present passing through the study area:

- SH-14 ; Baghpat-Sonepat- Meerut-Garhmukteshwar-Bulandshahar, also popularly known as Garh Road
- SH-18 ; Meerut-Hapur- Badaun also popularly known as Hapur Road
- SH-78 ; Meerut-Parikshatgarh-Garhmukteshwar
- SH-82 Meerut-Karnal, also known as Badhaut Road.

Figure 3-2 : Influence Area



The Meerut and Ghaziabad are presently connected with Delhi with intercity rail system. There are total 15 stations between Delhi and Meerut in route length of about 77 kms. List of Stations between Tilak Bridge and Meerut Cantt are as under.

- Tilak Bridge
- Mandawli Chander Vihar Halt
- Anand Vihar Halt
- Chander Nagar Halt
- Sahibabad
- Ghaziabad Jn.
- Naya Ghaziabad
- Guldhar
- Duhai Halt

- Murad Nagar
- Modi Nagar
- Muhiuddin Pur
- Partapur
- Meerut City Jn.
- Meerut Cantt

3.3 Survey and Studies

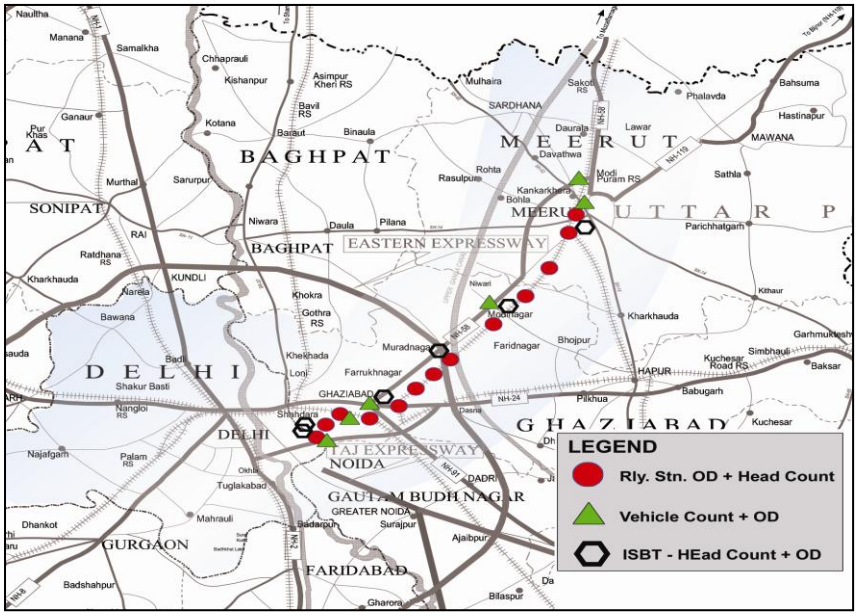
Extensive and in-depth surveys and studies have been carried out to appreciate the traffic and travel characteristics along the corridor. The various surveys conducted are given below.

Table 3-1 : Details of Traffic Surveys

Sl. No.	Survey Title	Days	Quantum
1	Origin Destination Surveys	2 week days & 1 week end	21 locations including rail and bus stations
2	Passenger Head Count surveys	2 week days & 1 week end	19 locations including rail and bus stations
3	Classified Traffic Volume Count Survey	16 hours	6 locations (4 Junctions,2 mid block)
4	Occupancy Survey	-	6 locations
5	Stated Preference Survey	-	Conducted covering various mode users. Data on about 14000 enumerations was captured from bus stops, railway stations and road side interviews.

In addition, large amount of secondary data was collected on socio-economic profile of project influence areas cities which formed basis for traffic demand forecasts.

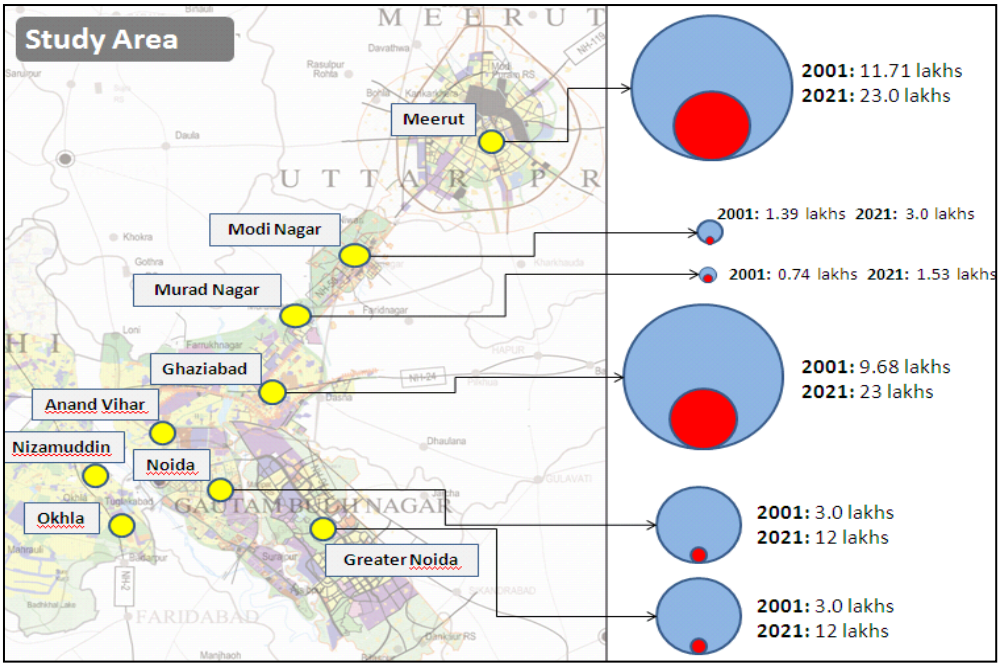
Figure 3-3 : Traffic Survey Locations



3.4 Demographic Profile along the Corridor

As part of the study, development plans of Delhi, Ghaziabad, Muradnagar, Modinagar, and Meerut have been studied. The development plans have projected the population and economic activities for each of the towns for the year 2011 & 2021 in accordance with the proposed development.

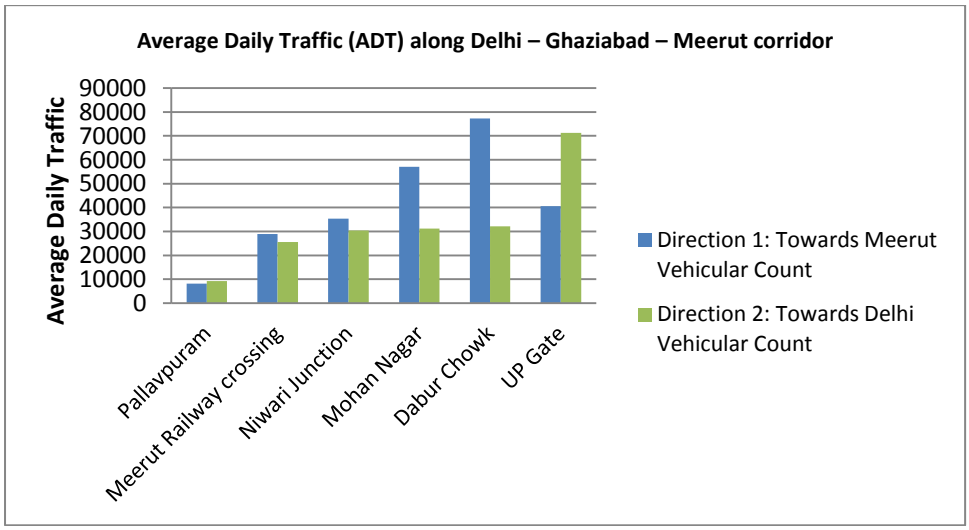
Figure 3-4 : Demographic Profile along the Corridor



3.5 Traffic Volume

The average daily traffic and modal composition of vehicles on a typical week day in both the directions along the corridor is given below.

Figure 3-5 : Average Daily Traffic from Delhi to Meerut direction per day



It may be observed that road traffic ranges from about 58000 PUCS to 102,000 PCUS between Meerut and Delhi at various locations.

The traffic composition indicates very high proportion of private vehicles consisting cars and 2 wheelers in traffic mix. The traffic at various locations along National Highway is given below.

Table 3-2 : Average Daily Traffic from Delhi to Meerut direction per day

Sr. No	Location	Vehicles*	PCUs*
1	Pallavpuram	17,463	23,784
2	Meerut Railway crossing	54,444	58,457
3	Niwari Junction	65,891	79,123
4	Mohan Nagar	88,220	85,107
5	Dabur Chowk	109,422	104,142
6	UP Gate	111,780	102,710
	* for 16 hours		

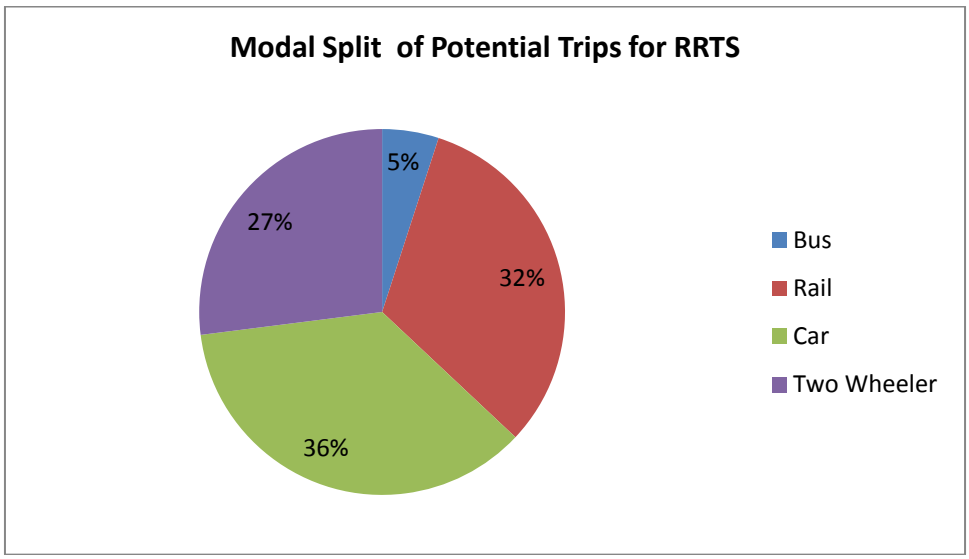
3.5.1. Rail and Bus Passenger Volume

The primary survey data collected at various stations and bus stops in the project influence area indicates that more than 2.5 lakh passenger make intercity travel in the project catchment between various origin destinations.

3.5.2. Travel characteristics of Base Year (2011) by Rail, Bus and Private Vehicles

The total passenger movement along the study corridor is 6,89,415 passengers per day. The modal share in figure below shows that maximum (36%) share of passengers is carried by car followed by 32% by Rail. Bus and rail together carry about 37 of total trips. The mode wise breakup of base year travel demand is presented in the following chart.

Figure 3-6: Modal Split of Potential Trips for RRTS



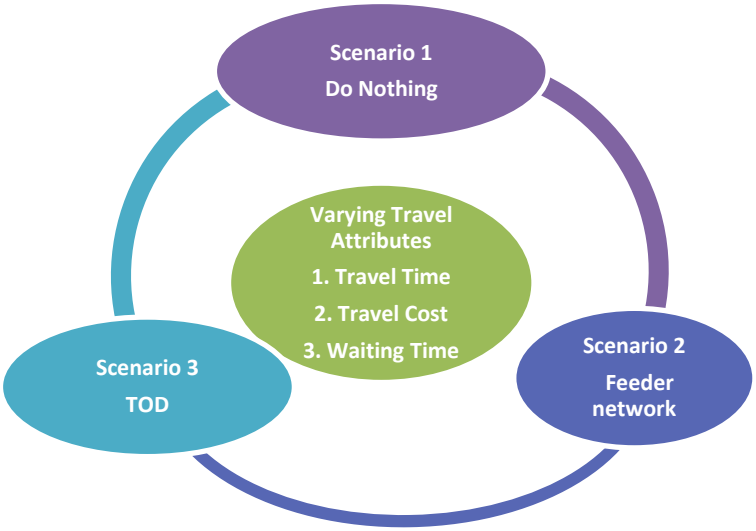
After estimating the potential catchment area trips, data collected by Stated preference surveys was analysed to arrive at binary logit mode choice model. The model is used to estimate shift from a given OD pair to RRTS based on the travel time, travel cost and waiting for that OD pair. This exercise of identifying the shift of travel from existing mode to RRTS is performed for each mode and the shift is

calculated using the fares, travel time and waiting times of the existing mode to that of RRTS. Shift estimated from various modes varied between 40 -60 percent.

3.5.3. Travel Demand Forecast Scenarios

The travel demand forecast study conducted for the project identified a range of scenarios of passenger forecasts for proposed RRT between 2016 and 2041. These scenarios take into account various influencing factors of travel time, travel cost and frequency together with the three growth situations: The three main scenarios considered are as follows:

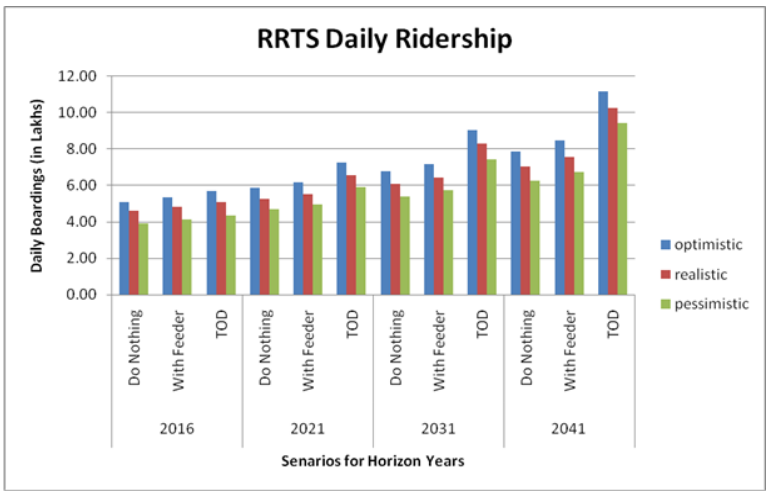
Figure 3-7: Travel Demand Assessment Scenarios



a) Scenario 1 - (Do Nothing)- Normal connectivity and Development without Feeder and TOD;
b) Scenario 2 – where bus feeder services are provided to a number of the railway stations;
c) Scenario 3 - feeder services and passenger traffic due to Transit Oriented Development (TOD) is included. TOD considers development of an area of about 1458 ha in proximity of stations from potential vacant land. This development is assumed to happen in phased manner with 10 percent development in 2016 increasing to 100 percent by 2041.

Figure 3-8: Estimated Daily Ridership

In addition to these scenarios, the Travel Demand Forecast Study examines 3 scenarios namely optimistic, Realistic and Pessimistic by varying attributes for travel time, travel cost and waiting time. The optimistic scenario considers shortest travel time, lesser costs and lower waits whereas pessimistic scenario considers longer travel



time, costly travel and more wait times.

In order to analyze further the traffic predictions, the annual growth, scenarios and cases were displayed on the chart shown in Figure 3-8. The vertical scale represents the daily total number of passengers boarding the trains on weekdays.

3.6 RRTS Parameters and Final Ridership

While the scenarios explained above provided a range of forecasts under various parameters, the ridership used for estimating revenue was based on fare levels (travel cost) derived from revenue optimization and willingness to pay of users. The travel time and frequency was also adopted from finalized operational plan in which RRT simulations were conducted. The impacts of providing concessional fares were also accounted while finalizing ridership. The final ridership is presented below. This is based on 62 minutes travel time between Sarai Kale khan- Modipuram , peak and off peak frequency as per operational plan and Rs1.07 per km fare as determined from WTP.

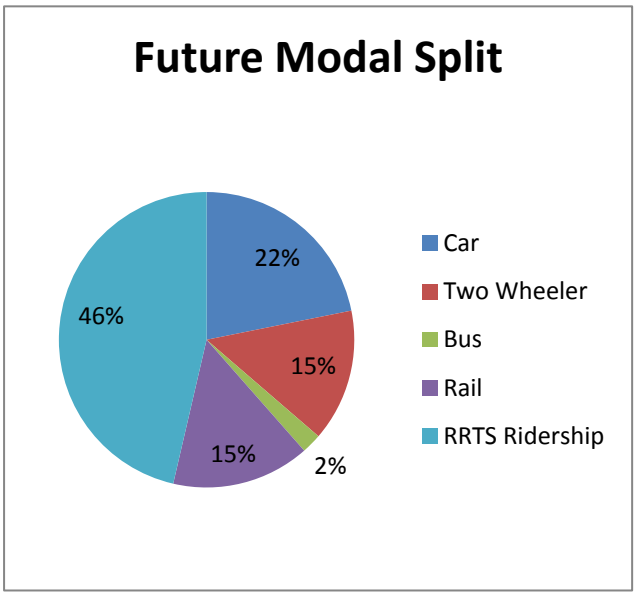
Table 3-3 : Daily Ridership

Sr. No	Year	Ridership per day
1	2016	570,203
2	2021	742,332
3	2031	919,612
4	2041	11,35,530

3.7 RRTS Impacts on Modal Share

The proposed RRTS would provide an efficient public transport for commuting between Delhi, Meerut and Ghaziabad. The system will provide substantial time savings apart from other benefits like comfort, safety etc. These characteristics will promote use of public transport in the region and modal split in favor of public transport will increase substantially. The future modal split in " With RRTS" situation is presented in Figure 3-9. It may be observed that public transport share post RRT will be 63 percent as against 37 percent presently.

Figure 3-9: Future Modal Split



4. REVIEW OF PRESENT RAILWAY & NH ALIGNMENT

4.1 Existing Condition Analysis

This chapter provides summary of the existing road and rail connectivity of influence area. The details are provided in Existing Condition Analysis Report.

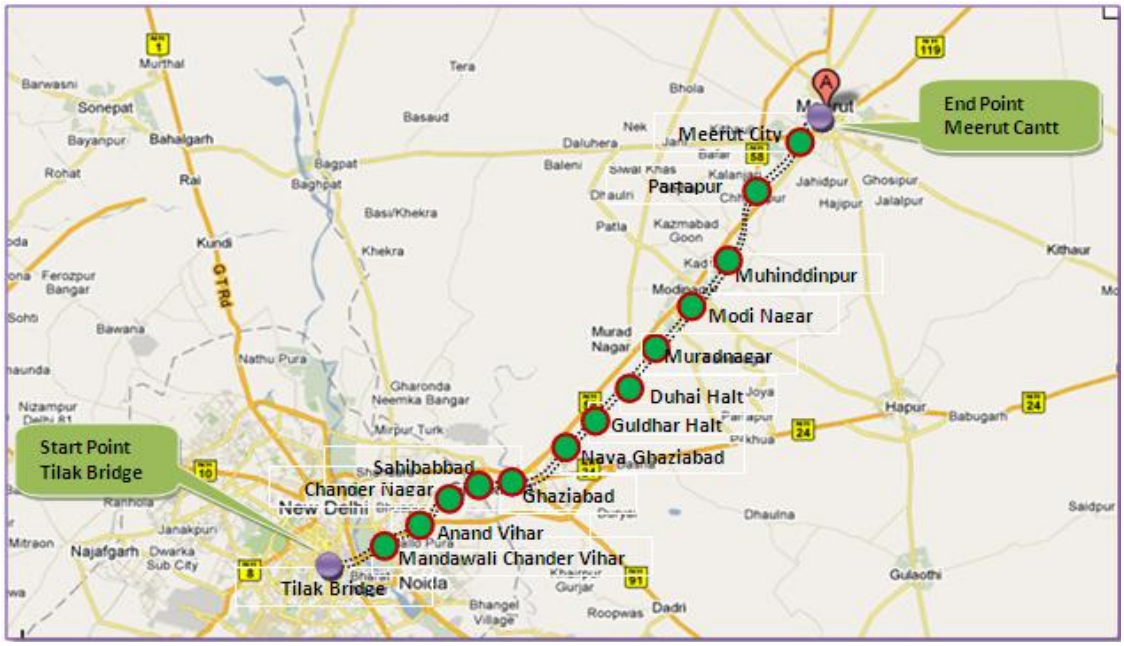
4.2 Existing Railway Alignment

The existing Northern Railway corridor between (figure 4-1) Tilak Bridge–Sahibabad and Sahibabad-Ghaziabad section is a multiple line electrified section. While the Tilak Bridge-Sahibabad section is a double-line section, the Sahibabad- Ghaziabad route has 4 lines. The Tilak Bridge-Ghaziabad Corridor is part of the Delhi- Howrah Group A route of Indian Railways. Maximum Permissible Speed of Tilak Bridge –Ghaziabad section is 110 kmph. These sections of Northern Railway are one of the busiest routes of Indian Railways.

Ghaziabad–Meerut corridor is a double line non-electrified section. Like the above sections, this is also a part of Delhi Division of Northern Railway. The Ghaziabad- Meerut Section is part of the Delhi- Ghaziabad- Meerut City-Saharanpur corridor. The maximum permissible speed of the section is 100 kmph except for Shatabdi, for which it is 105 kmph.

The line between Tilak Bridge –Ghaziabad-Meerut is At-grade. The main stations in the study area are Tilak Bridge, Ghaziabad, Murad Nagar, Modi Nagar and Meerut.

Figure 4-1: Existing Railway Alignment



4.2.1. Line Capacity Utilization on Delhi-Meerut Section

The line capacity utilization between Delhi – Meerut section is given in the Table 4.1. It may be noted that this line is oversaturated.

Table 4-1 : Line Capacity Utilization : Delhi – Meerut Section

Tilak Bridge – B Panel Corridor								
Charted Capacity (Trains)			As of now			Percentage Utilization		
Without MB	With 2 hrs MB	With 4 hrs MB	Passenger Trains	Goods Trains	Total	Without MB	With 2 hrs MB	With 4 hrs MB
80	70	60	60	40	109	136.3%	155.7%	181.7%
B Panel - Sahibabad Corridor								
Charted Capacity (Trains)			As of now			Percentage Utilization		
Without MB	With 2 hrs MB	With 4 hrs MB	Passenger Trains	Goods Trains	Total	Without MB	With 2 hrs MB	With 4 hrs MB
65	59	53	69	43	112	172.3%	189.8%	211.3%
Sahibabad - Ghaziabad Corridor								
Charted Capacity (Trains)			As of now			Percentage Utilization		
Without MB	With 2 hrs MB	With 4 hrs MB	Passenger Trains	Goods Trains	Total	Without MB	With 2 hrs MB	With 4 hrs MB
150	138	125	124	68	192	128%	139%	154%
Ghaziabad – Meerut Corridor								
Charted Capacity (Trains)			As of now			Percentage Utilization		
Without MB	With 2 hrs MB	With 4 hrs MB	Passenger Trains	Goods Trains	Total	Without MB	With 2 hrs MB	With 4 hrs MB
55	49	43	20.5	8.8	29.3	53.3%	59.8%	68.1%

(Source: Northern Railway)

4.2.2. Other Features

There are 22 passenger trains operating between Delhi – Meerut and 23 from Meerut to Delhi carrying over 2 lakh passengers in a day. The time taken by EMU between Delhi and Meerut is 2 hour and 21 minutes. The fare of various sections by Railway between Delhi-Meerut is given in the following Table.

The main stations on this line are Tilak Bridge, Ghaziabad, Murad Nagar, Modi Nagar and Meerut. It is seen that the Right of Way is generally limited, the section has 42 level crossings and has curves at 30 locations. There are 15 stations enroute which have built up area and are very congested. Line capacity for Delhi – Ghaziabad section is over saturated. In view of very high traffic density between Tilak Bridge and Ghaziabad and other constraints, the use of the existing Indian Railway Corridor for the introduction of RRTS system is not considered feasible.

Table 4-2 : Railway Fare between Delhi and Meerut

Train Service	Distance(km)	Class	Fare (Rs.)
Delhi- Murad Nagar	38	AC Chair Car	165
		Sleeper Class	120
		Second Seating	35
Delhi-Modi Nagar	54	AC Chair Car	165
		Sleeper Class	120
		Second Seating	38
Delhi-Meerut City/Meerut Cantt	71	AC Chair Car	165
		Sleeper Class	140
		Second Seating	43

4.3 Existing Road network

The road network connection of the Delhi–Ghaziabad-Meerut section is described below:

National Highways

The following National Highways are at present passing through the study area:

a) NH- 24 : Delhi- Ghaziabad-Hapur-Bareilly-Lucknow
b) NH-58 : Ghaziabad-Meerut-Haridwar-Badrinath-Mana Pass

NH-58 is the main and most used road link between Meerut and Delhi and carries most of the road traffic between NCT and Meerut/ Hardwar/ Dehradun. The Delhi – Meerut Buses start from Anand Vihar Bus Terminus.

State Highways

The following State Highways are at present passing through the study area:

a) SH-14 : Baghpat-Sonepat- Meerut-Garhmukteshwar-Bulandshahar, also popularly known as Garh Road
b) SH-18 : Meerut-Hapur- Badaun also popularly known as Hapur Road
c) SH-78 : Meerut-Parikshatgarh-Garhmukteshwar
d) SH-82 : Meerut-Karnal, also known as Badhaut Road.

The journey times from Delhi to Meerut is about 2 hours to 2 hours and 45 minutes by Rail or Road.

The National Highway 24/58 connecting Delhi and Meerut generally follows flat or gently undulating terrain at grade with grade separation at two locations. NH 24 has 6 lanes between the Delhi – Mohan Nagar section with the ROW of 66.96 m. Ghaziabad to Partapur section of NH 58 is 4 lane divided highway with ROW of 36.58 m. The ROW for the rest of the section is varying from 49 m to 65m. The townships are developed generally along the National Highway-58, which also has

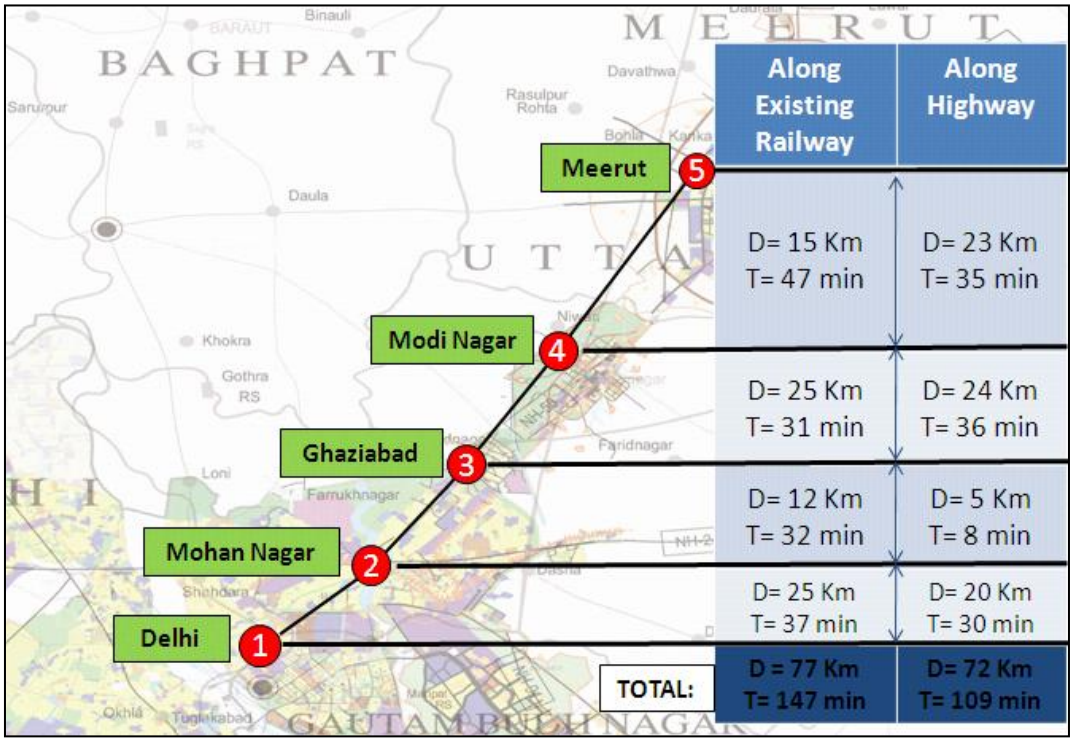
strong potential for Transit oriented Development (TOD) at several places. A good feeder network can be provided if the alignment is build along the National Highway.

Based on above considerations and analysis of potentials and considerations, RRTS alignment was recommended to be placed along NH58.

The Green field option along the proposed Delhi – Meerut Expressway for the RRTS alignment is also a possibility; however, as it is far away from the habitation and because of land acquisition costs it did not appear feasible.

The journey time by existing rail and road is shown in figure 4-2.

Figure 4-2: Journey Time



5. PROPOSED ALIGNMENT

5.1 Alignment Finalization Process

The Alignment for Delhi Ghaziabad Meerut RRTS corridor has been finalized after detailed evaluation of the project corridor through collection of relevant data and analysis of various alternative alignments chosen for the study along the corridor. This chapter presents a summary of the findings of the alignment finalization process along with details of the finalized alignment. A detailed report "Evaluation of Alternatives and Proposed Alignment Report" has already been submitted as a part of deliverables for the project that may be referred to for any further details.

The figure below presents the alignment finalization process followed:

Figure 5-1: Alignment Finalization Process

5.2 Alignment Contours

The alignment originates from R.H Side of existing (facing New Delhi) Nizamuddin railway station of Northern railway/ Sarai Kale Khan. The proposed “Hz. Nizamuddin / Sarai Kale Khan” station of RRTS will be underground and will serve as terminal station integrated with two more underground routes namely DMRC Phase III and RRTS Alwar – Delhi corridor, the center line of Hz. Nizamuddin RRTS station has been taken as “Zero” Chainage. The route will continue towards Anand Vihar Station at CH: 9700 the alignment will be underground. The particular stretch of underground alignment will have the special feature to highlight that the alignment will cross “Yamuna river” underground through two separate tunnels.

The Anand Vihar RRTS station is also underground due to heavy built up area over ground. This station is located at ch. 9700.00. This station will integrate with DMRC Metro station, ISBT and Indian Railway. The route after Anand vihar will continue towards Sahibabad RRTS Station at Ch. 16400.00 partially underground and partially elevated. The underground section starts ramping up near Vishali Metro Station from Ch. 12900.00 and comes over ground at Ch. 13520.00 there after alignment will follow NH58 on RH side to reach Sahibabad RRTS Station

After Sahibabad Station, the alignment will continue to the RHS of the road well ahead of the Mohan Nagar Fly Over to avoid the heavily built up area on the LHS near the Fly Over. The alignment crosses the Railway tracks between the fly over and the Mohan Meakin Factory in a narrow corridor and runs between the road and the factory boundary before turning right through a sharp curve (due to space constraint, as the Mohan Meakin Factory Premises is to be avoided) to follow the GT road. The Alignment runs on the Median of the GT Road as the proposed Metro alignment (Extension of Dilshad Garden Metro to Mohan Nagar) is proposed on the left hand side of the road. On its way towards Hindon River, Elevated Mohan Nagar Station is proposed at Ch; 18800.00 on the Median of the road. After Mohan Nagar Station, it continues on the RHS of the road and runs along the road till it reaches Hindon River, where it will move away from the Hindon Bridge to cross the river. After crossing Hindon River the alignment again comes back to the Road side and continues to run on the RHS of GT Road before turning left to join the NH58 at Meerut Road Crossing. The alignment runs on the median of NH 58 and Ghaziabad Station is proposed at CH: 21300.00 on the central verge of the road. After Ghaziabad Station the alignment continues on the median of NH58 and Guldhar Station is proposed at CH: 24600.00.

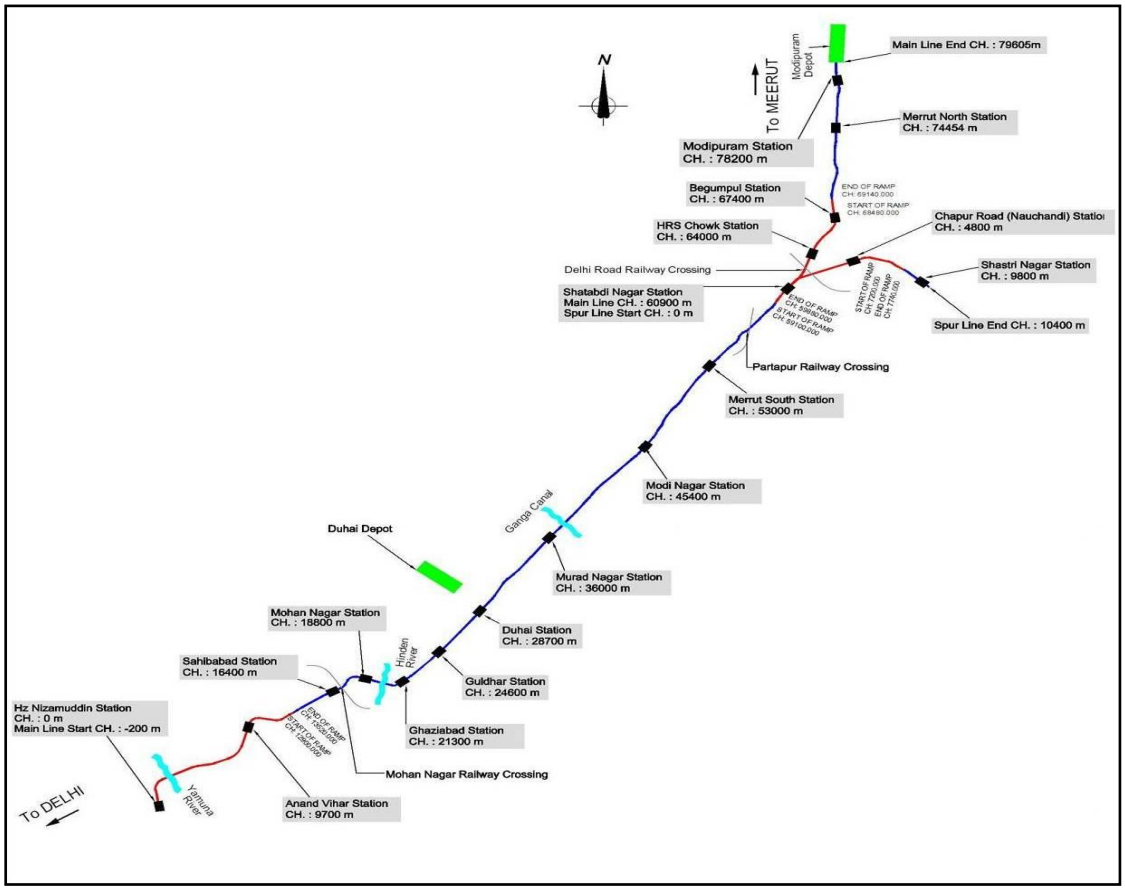
After the elevated Guldhar Station the alignment runs elevated on the central verge of the road till Duhai where Duhai Station is proposed at CH: 28700.00. After Duhai Station the alignment continues towards Meerut on the median of the road till it approaches Gang Canal. The alignment is shifted to the left hand side of the road to facilitate the crossing of the canal. The Murad Nagar elevated Station is proposed at CH: 36000.00. The Murad Nagar Station is proposed close to the canal because the proposed Upper Ganga Canal Expressway is planned to pass along the canal. After Murad Nagar Station, the alignment continues on the left hand side till it crosses the Gang Canal. After crossing the canal the alignment is shifted back to the central verge of the NH 58 and continues on it till Modi Nagar Station. The Modi Nagar Station is proposed on the central verge of the road at CH: 45400.00. The Modi Nagar Station has been proposed close the Niwari Road junction so that commuters from Niwari side are also served well.

After the elevated Modi Nagar Station the alignment continues on the median of NH 58 and Meerut South Station is proposed at CH: 53000.00. The Meerut South Station is proposed close to the location of crossing of Meerut Outer Ring Road and NH 58. After Meerut South Station the alignment continues on the median of NH58 till it approaches Partapur Flyover.

Before Partapur Flyover, the alignment is shifted to the left hand side of the flyover to avoid heavily built up area on the right hand side. It runs parallel to the flyover and shifted further left to avoid heavily built up area. It will take a curve to cross the Railway line. A few private properties are affected. It comes back to the median of Delhi Road (The NH 58 bye- passes Meerut City at Partapur flyover) at a distance of approximately 1.5 km from the Partapur Fly-over. The Alignment runs on the median of Delhi Road and goes underground through a switch-over ramp proposed at CH: 59100.00 and Shatabdi Nagar Underground Station is proposed at CH: 60900.00. As per the proposed alignment Shatabdi Nagar will function as junction station as one spur line originates from this station and extended up to Shastri Nagar at Ch. 9800.00 covering 10.5 kms.

The main line alignment continuing as underground and will connect Meerut Central underground station at Ch. 64000.00. This station will serve for old city population of Meerut. Again the alignment will go underground up to Begumpul station at Ch. 67400.00.

Figure 5-2: Alignment Map



After Begum Pul Underground station, the alignment continues underground towards north till it reaches Mall Road- Roorkee Road Junction. After the Junction, the alignment becomes elevated through a switch –over ramp proposed on the Right

Hand Side of Roorkee Road. The elevated alignment is shifted to the central verge of the road and continues on the median till it approaches Pallavpuram Flyover the alignment on the right side of the flyover to avoid the crossing.

After crossing / passing the Flyover, the alignment comes back on the median of the road (NH 58) and continues on the median towards Pallav Tower. The Elevated Meerut North Station is proposed opposite Modi Rubber Factory on the median of NH58 at CH: 74454.00

After Meerut North Station the alignment is continues elevated to connect Modipuram Station at Ch. 78200.00. this station will function as terminal station of RRTS having a big depot immediately after this RRTS station which will located on at grade alignment. Alignment map and stations are presented in figure 5-2.

5.3 Stations Along the Alignment

The following table 5-1 summarizes the location of stations along with other details.

Table 5-1 : Proposed Stations along the Corridor with Route Length

Sr. No	Stations	Elevated	Underground	Total
	Project Start	0.000	0.200	0.200
1	Sarai Kale Khan – Anand Vihar	0.000	9.700	9.70
2	Anand Vihar – Sahibabad	3.240	3.460	6.700
3	Sahibabad – Mohan Nagar	2.400	0.000	2.400
4	Mohan Nagar – Ghaziabad	2.500	0.000	2.500
5	Ghaziabad – Guldhar	3.300	0.000	3.300
6	Guldhar – Duhai	4.100	0.000	4.100
7	Duhai – Muradnagar	7.300	0.000	7.300
8	Muradnagar – Modinagar	9.400	0.000	9.400
9	Modinagar – Meerut South	7.600	0.000	7.600
10	Meerut South – Shatabadi Nagar	6.480	1.420	7.900
11	Shatabadi Nagar – HRS Chowk	0.000	3.100	3.10
12	HRS Chowk – Begumpul	0.00	3.400	3.400
13	Begumpul – Meerut North	5.634	1.420	7.054
14	Meerut North- Modipuram	3.746	0.000	3.746
	Main Line Ends	1.405	0.000	1.405
	Spur Line			
15	Shatabadi Nagar – Hapur Road (Spur)	0.00	4.800	4.800
16	Hapur Road – Shastri Nagar (Spur)	2.380	2.620	5.000
	Spur Ends	0.600	0.000	0.600
	Total	**60.085**	**30.120**	**90.205**

6. KEY INPUTS FROM ENGINEERING AND OPERATIONS REPORT

6.1 Introduction

A detailed engineering study along with topography survey and geo-technical investigation has been conducted to understand the engineering feasibility of the project and establish various engineering parameters for the project. A separate Engineering and Operations Report is being submitted along with the Feasibility Report that may be referred to for additional details. This chapter summarizes some of the key elements of the engineering study.

6.2 Rolling Stock Demand

Rolling Stock requirement has been determined based on the Travel Demand Forecast made in the study submitted earlier for the project.

6.3 Rolling Stock Selection

Physical attributes derived from the demand for rolling stock are summarized below :

- operating headway of 4 minutes (9 coach) at Ultimate System Capacity (2041);
- operating headway of 5 minutes (6 coach) at Opening System Capacity (2016);
- cars of 3.66 metres external width;
- three double doorways per bodyside of 1.5 metres nominal width;
- one wheelchair position per driving train;
- seat pitch of 800 mm arranged airline-style;
- preferred maximum standing passenger density of 3 per square metre;
- no tables;
- no toilets;
- no catering facilities;
- no equipment cabinets within the saloons;
- no bicycle accommodation;
- no train crew accommodation (other than the drivers).

The number of train units required is estimated based upon the number of ECS moves used to form the first passenger trains of the day. This amounts to 28 to which we recommend a 10% contingency be added leading to a total of 31 units required in 2041.

Because 12 trains per hour of 6 cars in 2016 and 9 cars in 2031 can cope with the demand in those years the Guldhar services can be eliminated in those years reducing the total number of units required by 3 to 28.

When the system opens in 2016 the minimum number of coaches required will be 168. (28 * 6) In 2021 the Guldhar services are required to cope with demand this needs an extra 3 units or 18 (3 *6) cars.

In 2031 the adoption of 9 car operation reduces the required service frequency back to 12 freeing up 3 units. The 12 non driving cars of these units could be used to lengthen four others to 9 cars, to lengthen the remaining 24, 6 car units would require 72 (24*3) new cars to be bought, bringing the total to 252 cars. The 6 driving cars from the disbanded sets on the Delhi – Meerut line, until 2041, may find use on other lines in the interim else to lengthen other trains.

By 2041 15 trains per hour are again required, the 6 driving cars released in 2031 are formed up in to 9 car sets with (3*7 =) 21 non driving cars making a total of 279 cars.

The above is summarised in the following table:

Table 6-1 : Rolling Stock Requirement for each year

Year	No. cars / train	tph	Units	Driving cars	Non driving cars	Total Cars
2016	6	12	28	56(56)	112(112)	168(168)
2021	6	15	31	62(6)	124(12)	186(18)
2031	9	12	28	56(0)	196(72)	252(72)
2041	9	15	31	62(0)	217(21)	279(21)

Note: numbers in brackets are the number of cars to be bought in that year

6.3.1. Train Requirements

There are range of EMU options including those operating with a.c. overhead line (OHL), d.c. 3rd Rail, d.c. OHL and Dual Voltage (a.c./d.c.). Articulated and double decker variants. However for Delhi-Meerut corridor, EMU with AC overhead line is considered.

Whilst a double deck solution may be favourable to maximise seated capacity, in this application where the standing capacity is also to be maximised many of the benefits are lost. Dwell times would also be extended as the number of doors per vehicle would also be restricted. It is for this reason that this option is not recommended and single deck is preferred.

The parameters shown in Table below are those selected to provide the optimum train and train services:

Table 6-2 : Train Parameters

Parameter	At Opening System Capacity	At Ultimate System Capacity
Peak Hour System Capacity, PHPDT	15,238	26,462
Operational Headway, minutes	5	4
Required Train Passenger Capacity	1,270	1,764
Nominal Car Length, metres	24	24
Nominal Car Width, metres	3.66	3.66
Rail Gauge, mm	1,676	1,676

Seating Layout	2 + 3	2 + 3
Style of Seat Layout	Airline	Airline
Seat Pitch, mm	800	800
Density of Standing Passengers in Normal Service, per square metre	3	3
Number of Cars per Train	6	9
Train Stopping Accuracy at Stations, metres	10	10
Number of Doorways per Bodyside	3	3
Nominal Width of the Bodyside Doors, metres	1.5	1.5
Number of Wheelchair Positions per Car	1	1
Toilets on the Trains	No	No
Tables on the Trains	No	No
Catering Facilities on the Trains	No	No
Bicycle accommodation on the Trains	No	No
Train Crew Accommodation on the Trains (other than the drivers)	No	No
Train Type	25 kV EMU	25 kV EMU
Train Configuration	6 car	9 car
Regenerative Braking Required	Yes	Yes
Cab-end gangways with close-off doors	Yes	Yes
Passenger Saloons and Driving Cabs to be Air Conditioned	Yes	Yes
CCTV in the Trains	Yes	Yes
Maximum Train Speed, km/hr	160	160
Maximum Initial Train Acceleration, m/s²	1.0	1.0
Initial Train Acceleration to be Independent of Train Weight	Yes	Yes
Maximum Braking Rate, m/s²	1.0	1.0
Emergency Braking Rate, m/s²	1.3	1.3
Stop-all-stations Journey Time from Sarai Kale Khan to Modi Puram, minutes	62	62
Number of Trains to be Provisioned	28 (6 coach)	31 (9 coach)
Number of Cars to be Provisioned	168	279
Track Gauge	1676 mm Indian Broad Gauge	
Track Structure	ballastless track structure on main running lines	
Rail	60kg/m	
Signalling	CATC	
Nominal height of the coach	3.9 m	
Axle load	20 tonnes	

Train lengths	6, 9 cars
Train composition 6 coach	DMC TC MC MC TC DMC
Train composition 9 coach	DMC TC MC MC TC MC MC TC DMC
Maximum speed	160 kph. Design speed 180 kph
Capacity of one Driving coach	91 seats, 115 standing, 1 wheel chair
Capacity of one motor/trailer coach	101 seats, 124 standing, 1 wheel chair
Emergency passenger evacuation	Through front of driving cab

6.4 Train Sectional Running Time Calculation

The estimates of running time required the construction of a computer simulation of the system taking into account the alignment and known rolling stock parameters. RailSys simulation tool was used for modeling of train interactions based on signaling, traction capability and infrastructure.

The alignment and infrastructure was built in simulation model. In order to attain the desired journey times on the RRTS, the maximum line speed for the route has been set to 180 km/h. The impacts of the different running speeds have been addressed by limiting the maximum speed of the simulated trains rather than adjusting the infrastructure for each scenario. The points at which the gradients change have been incorporated into the simulation model. An example of the infrastructure modelled is shown below in Figure 6.1.

Figure 6-1: Alignment Map Example of Potential Track Layout at Shatabdi Nagar

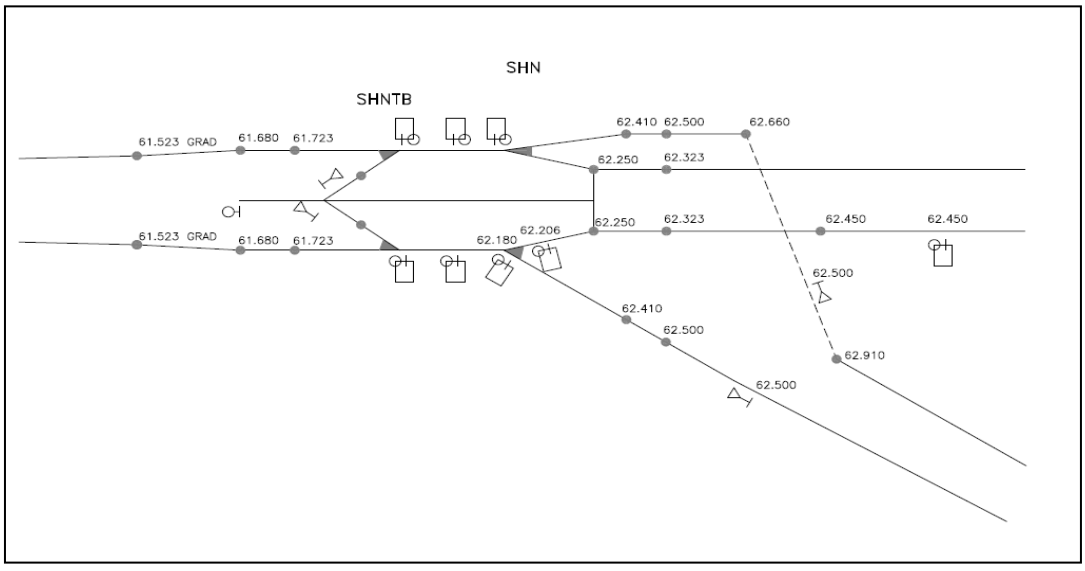
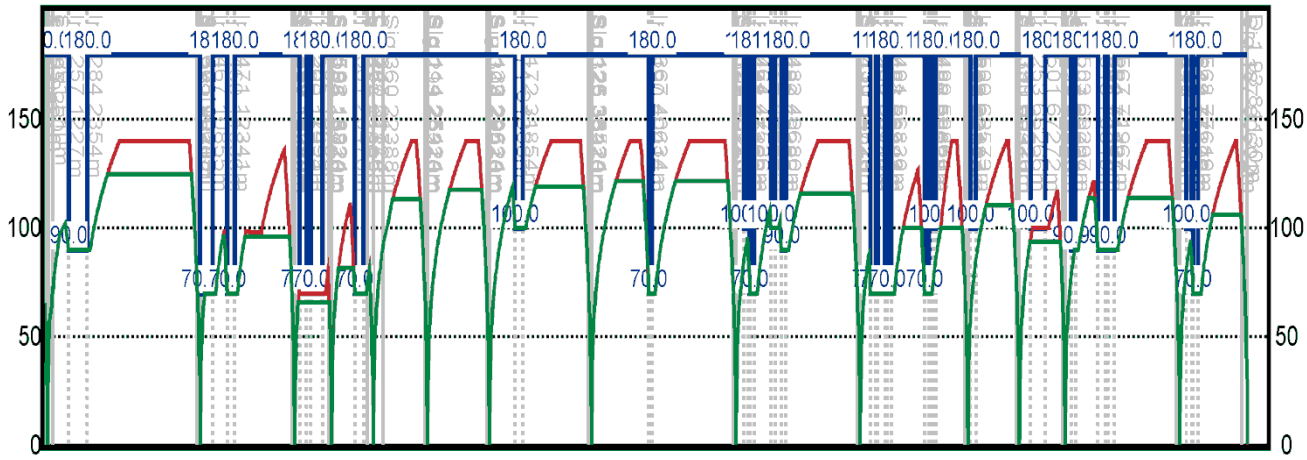
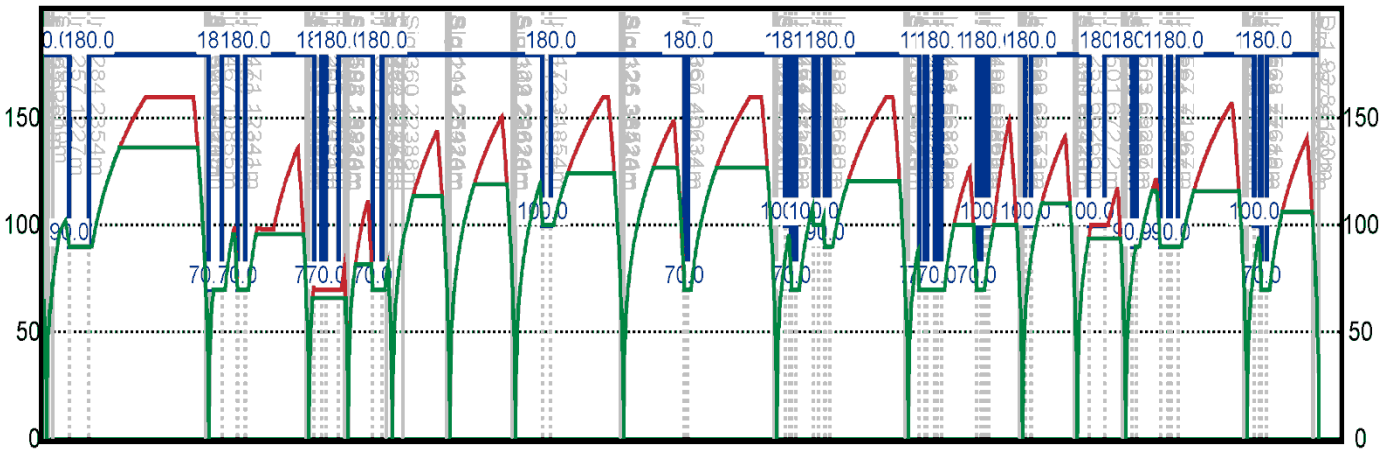


Figure 6-2: Distance v. Speed, down stopping service, 140 km/h



Simulation shown in figure 6.2 it may be seen that, the train is able to reach 140 km/h in 10 inter-station sections again showing that significant time could be saved by running faster.

Figure 6-3: Distance v. Speed, down stopping service, 160 km/h



In the above graphs, the blue line indicates the civil speed limit for the alignment. The curves of less than 1500m radius and their associated speed limits can be clearly seen. The red line indicates the performance of the train running at its simulated maximum speed and the green line shows the 'scheduled' speed including a 5% running time margin to account for variations in driver behaviour, variations in traction performance and to give some built in recovery to any subsequent timetables. This margin can be varied and is user definable but 5% is a typical value for a high frequency multi-station operation such as the RRTS. Adjusting the margin permits the inclusion of more or less recovery time to cope with inevitable operational perturbations.

With a maximum train speed of 160 km/h, the all stations stopping service can reach its maximum speed on 4 out of 14 inter-station sections showing that the opportunity for time saving by going faster is becoming limited.

With the speed raised to 180 km/h, the train is only able to achieve this speed on one inter-station sections. The inter-station distances do not appear to justify the use of 180 km/h rolling stock for mainly stopping services.

Table below gives an indication of the overall travel time, excluding dwells for all stops service between overall journey times between Sarai Kale Khan and Modipuram and the relative differences between the different speed scenarios. Table below does the same for a non stop journey.

Table 6-3 : Travel time comparison, by overall line speed, for an all stopping service from Sarai Kale Khan to Modipuram

Scenario	A	B	C	D
Line Speed (km/h)	120	140	160	180
Travel time (hh:mm:ss)	00:56:28	00:54:31	00:53:37	00:53:04
		A-B	B-C	C-D
		00:01:57	00:00:54	00:00:33

Table 6-4 : Travel time comparison, by overall line speed, for a non stop service from Sarai Kale Khan to Modipuram

Scenario	A	B	C	D
Line Speed (km/h)	120	140	160	180
Travel time (hh:mm:ss)	00:47:42	00:43:39	00:41:00	00:39:19
		A-B	B-C	C-D
		00:04:03	00:02:39	00:01:41

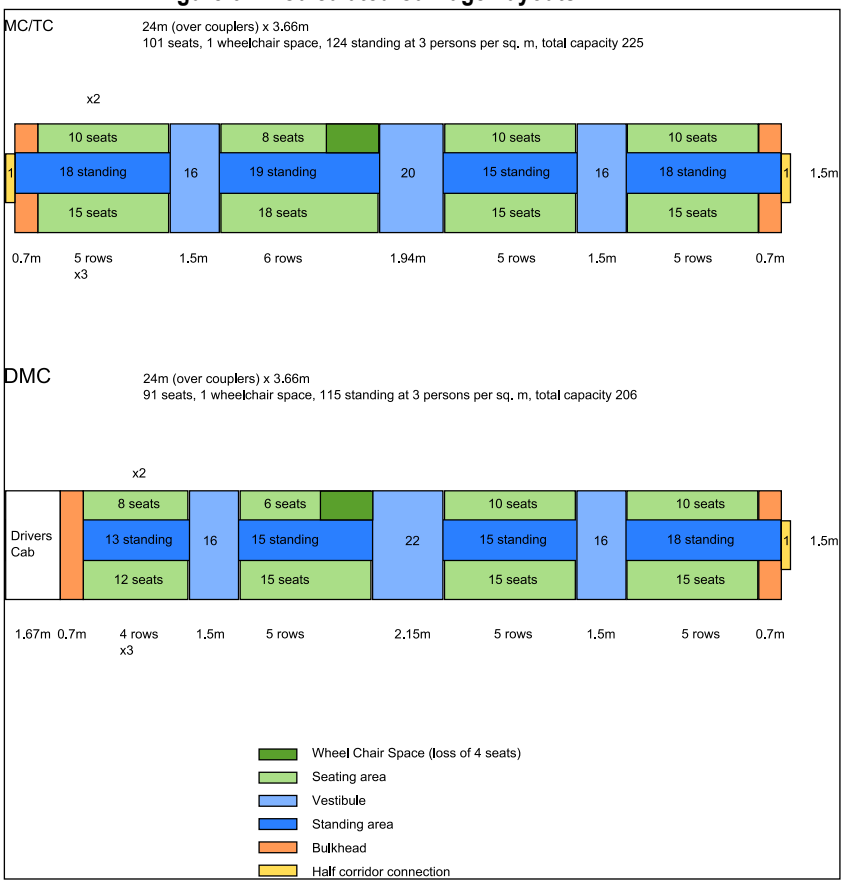
In both the non-stop and stopping case the reduction in journey time between adjacent speed bands decreases as speed increases. For stopping services the optimum line speed appears to be 160 km/h as a further increase to 180 km/h would only yield a further 33 seconds.

For non stop services increasing to 180 kmh would save 1 minute and 41 seconds which would be desirable; however, this is for a completely non stop service and the actual saving would be less for a realistic service. Additionally, as a mix of stopping and non stop services is anticipated, it is better from a capacity point of view to stick with 160 km/h. We recommend therefore that the line be built to 160km/h and this is what we will assume in the rest of this report.

6.5 Train Capacity Calculation

In order to calculate the seating and standing capacity a number of assumptions were made. The seating and standing areas of the coach as well as the number of seats and standing spaces are shown in the following figures. Standing is taken as 3 persons per sq m for the purpose of ascertaining capacity of the coach.

Figure 6-4 : Calculated Carriage Layouts



The trains will consist of 6, 9 or 12 coaches. Composition of the trains will be as under:

6 coach train : DMC–TC–MC–MC–TC-DMC
9 coach train : DMC-TC-MC-MC-TC-MC-MC-TC-DMC
12 coach train: DMC-TC-MC-MC-TC-MC-MC-TC-MC–MC–TC-DMC

Table 6-5 : Passenger Capacity of Coaches

Result	Value
Total seats per DMC	91 + 1 wheel chair
Total seats per MC/TC	101 + 1 wheel chair
Total standees per DMC at 3 persons per m2	115
Total standees per MC/TC at 3 persons per m2	124
Total capacity of DMC	206 + 1 wheel chair
Total capacity of MC/TC	225 + 1 wheel chair

Table 6-6 : Passenger Capacity of Trains

No. of cars	Total capacity
6	1314 + 6 wheel chairs
9	1990 + 9 wheel chairs

6.5.1. Identifying Dwell Times

Demand data identifies the number of boarding and alighting passengers forecast at each station per day, split by direction. For each direction the sum of these values gives the total number of passengers using the station in a day and peak hour factor of these values gives the number of passengers using each station in the peak hour. The train frequency at each station is known as is the number of doors in each train, therefore the number of passengers using each door can be calculated. The table below shows station wise dwell time which varies from 20 – 47 sec on various stations.

Table 6-7 : Minimum dwell times in 2021 and 2041

Station	Dwells (seconds)			
	2021 6 car operation		2041 9 car operation	
	Forward	Backward	Forward	Backward
Shastri Nagar	27	23	29	29
Hapur Road	30	25	29	29
Modipuram	19	18	19	19
Meerut North	25	22	24	27
Begum Pul	27	23	27	27
Meerut Central	28	24	30	29
Shatabdi Nagar	23	21	24	24
Meerut South	22	20	26	26
Modinagar	40	32	41	41
Muradnagar	27	23	27	27
Duhai	32	27	42	42
Guldhar	22	20	24	24
Ghaziabad	47	37	46	46
Mohan Nagar	25	22	25	25
Sahibabad	23	20	22	23
Delhi (Anand Vihar)	30	25	29	29
Saraikale khan	49	38	47	47

6.6 Infrastructure

Based on the simulation results various infrastructure facilities were assessed and presented below.

6.6.1. Guldhar

A middle platform is required in which Guldhar services can terminate; however, it must be a through platform so that trains can arrive and depart to Duhai depot without shunting.

6.6.2. Meerut South

In the developed timetable all trains arrive from and depart to the Delhi direction so it only requires a bay platform; however, at least passive provision should be made for through running to maximise the flexibility of the layout.

6.6.3. Shatabdi Nagar

Separate platforms are advantageous for Shastri Nagar and Modipuram services: this arrangement will help to prevent a problem on one branch affecting the other.

6.6.4. Shastri Nagar

With a service frequency of 3 trains per hour in the developed timetable, only one platform is required; however, it is recommended that two platforms with a crossover in the throat are provided to allow a service to be maintained in the event of serious disruption.

The proposed alignment configuration and infrastructure is presented in figure 6.5.

The public time table and working time table is given in Annexure 1.

6.7 Depot and Stabling Operational Strategy

All rolling stock will return to either Modipuram Depot or Duhai Depot for overnight cleaning and servicing. The following table shows the stabling requirements at both depots in 2041.

Table 6-8 : Rolling stock stabling in 2041

Year	Modipuram Depot	Duhai Depot	Total
2041	21(includes 3 spare)	10	31

Given that the facilities differ between depots it is important that the diagrams are rotated so that each train set visits Modipuram depot on a regular basis for maintenance.

The number of drivers required varies substantially according to the drivers' service terms and conditions change. For calculation we have adopted 142 drivers considering LST 8 and 2 days off per week.

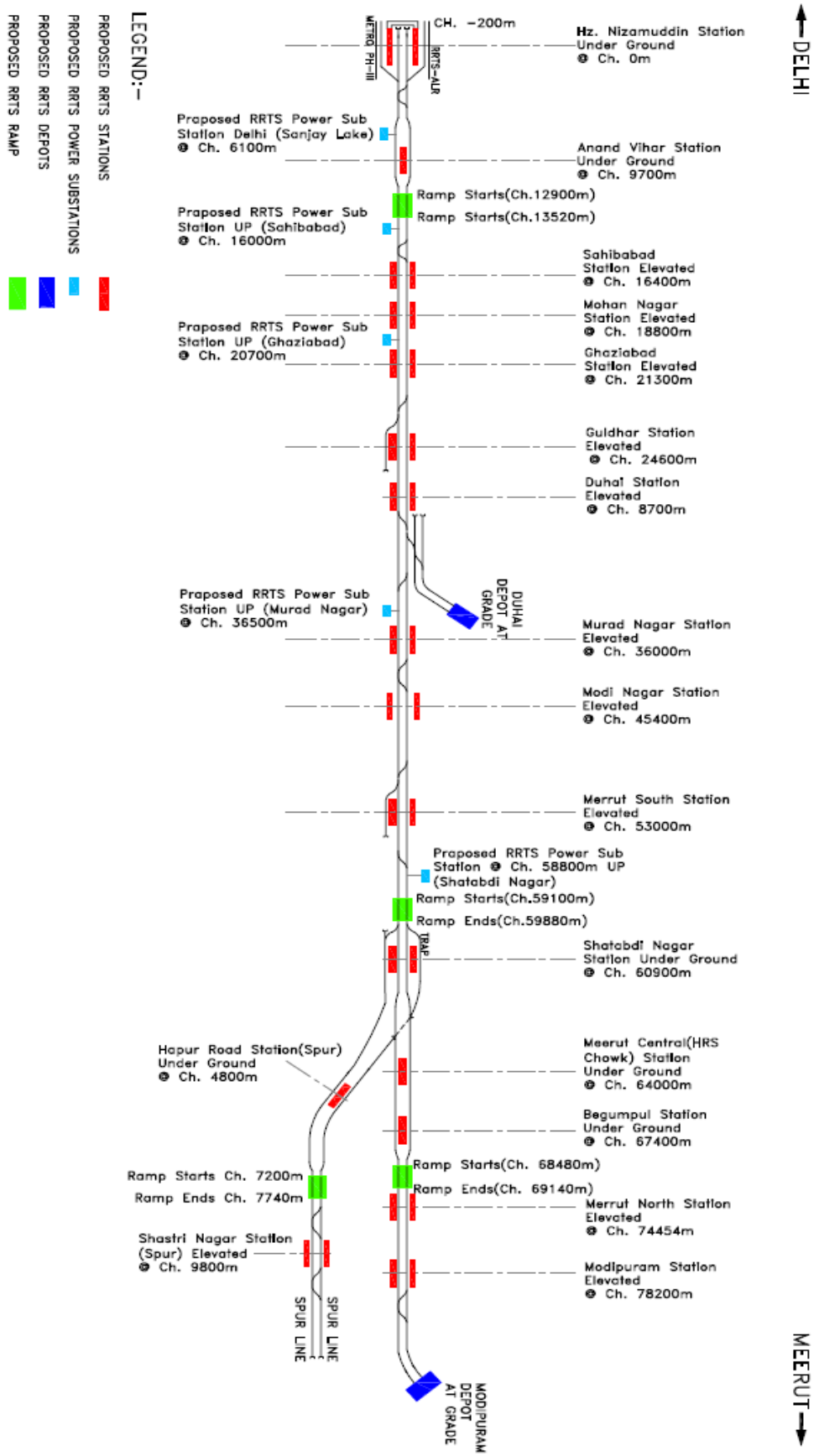
6.7.1. Track Gauge

Indian Railway follows broad gauge (1676mm) and going in for unified broad gauge and converting all other gauges of the network to Broad Gauge. Keeping this in mind and also the higher carrying capacity of Broad Gauge, it has been decided in TOR of the study to adopt this for the RRTS project.

6.7.2. Speed and Axle Load

Resulting from the traffic and operation study, various alternative speeds of trains, coach types and train compositions were evaluated to determine what is the optimum speed and train composition, for enabling the RRTS to carry the projected passengers. It was found that trains of 6 or 9 coach lengths, running at 160kmph are best suited to move the projected traffic. Discussion with the client has also confirmed that the maximum operating speed of 160 kmph is suitable. The track should therefore be fit for 160kmph operational speed and 180 kmph design speed. Similarly, the design axle load is finalized as 20 tonnes, and the track therefore needs to be designed for this axle load.

Figure 6-5: Proposed Alignment Configuration and Infrastructure



6.7.3. Ruling Gradient

It has been decided to adopt a maximum gradient of 1:100 (compensated) on the elevated viaduct portion of the track. The compensation will be at the rate of 0.04% per degree of curvature as adopted in the Indian Railways Permanent Way Manual. On the switch over portion from underground to surface, the maximum gradient permissible has been kept at 1:33.

6.7.4. Curves

The nature and degree of curves will depend on the final alignment. Vertical curve shall be provided only at the junction of grades when the algebraic difference between the grades is equal to or more than 0.4%. It is suggested that the minimum radius of the vertical curve shall be 4000 metres for the RRTS since this is a high speed route. The length of the vertical curve shall be determined by the formula L=RQ, where L is the length of the vertical curve, R is the radius, Q is the difference in percentage of gradients, expressed in radians.

Horizontal curves should be of minimum 1500 metres radius for a speed of 160 kmph. Where this radius cannot be achieved due to topographical conditions, the speed of the train has to be reduced. The Meerut-Delhi corridor has a radius of 500 metres at some locations. On a curve of 500 metres radius, the permissible speed will come to 90kmph,:

For the RRTS corridor, at 160 Kmph speed, on a radius of 1500 metres, a Cant of 155 mm and Cant deficiency of 100 mm will be adequate.

Transition curves will need to be provided wherever there is a change in radius of the track. As per IR PWay Manual para 407 for Broad Gauge Track.

The statement of horizontal curves is given in table 6-9 and table 6-10.

Table 6-9 : Statement of Horizontal Curves (Main Line)

Statement of Horizontal Curves (Main Line)											
Curve No.	Direction	Radius	Deflection Angle			Transition Length	Tangent Length	Arc Length	Curve Length	Total Curve Length (M)	Maximum Permissible Speed (KMPH)
			D	M	S						
1	R	800	73	32	15.34	100	648.19	926.71	1026.710	1126.710	120
2	R	1500	16	41	7.95	120	280.03	316.79	436.790	556.790	160
3	L	1500	12	56	14.78	120	230.12	218.67	338.670	458.670	160
4	L	1500	51	26	27.03	120	782.75	1226.69	1346.690	1466.690	160
5	R	500	83	35	50.08	110	502.95	619.30	729.300	839.300	95
6	L	500	45	15	4.05	110	263.82	284.67	394.670	504.670	95
7	R	5000	01	46	12.55	40	97.24	114.48	154.480	194.480	160
8	R	2600	05	49	56.41	70	167.44	194.66	264.660	334.660	160
9	L	600	35	43	44.13	110	248.66	264.00	374.000	484.000	105
10	R	500	79	21	12.93	110	470.62	582.27	692.270	802.270	95
11	R	2400	04	45	37.7	65	132.26	134.40	199.400	264.400	160
12	L	2700	04	09	9.55	60	127.89	135.69	195.690	255.690	160
13	L	500	55	00	22.48	110	315.85	369.80	479.800	589.800	95

14	L	2500	07	04	19.07	65	186.99	243.57	308.570	373.570	160
15	R	4000	01	44	46.8	40	80.96	81.92	121.920	161.920	160
16	L	7000	03	09	8.70	25	205.12	360.14	385.140	410.140	160
17	L	7000	00	53	4.58	25	66.54	83.07	108.070	133.070	160
18	L	5000	00	28	49.39	40	40.96	1.92	41.920	81.920	160
19	L	1500	08	17	28.88	120	168.65	96.86	216.860	336.860	160
20	R	1250	17	28	47.58	135	259.54	245.93	380.930	515.930	150
21	L	3200	08	38	16.13	60	271.67	422.42	482.420	542.420	160
22	L	3000	02	37	23.91	55	96.19	82.35	137.350	192.350	160
23	R	3000	03	40	32.74	55	123.77	137.46	192.460	247.460	160
24	L	5000	01	43	49.67	40	95.51	111.01	151.010	191.010	160
25	R	5000	02	08	44.42	40	113.63	147.25	187.250	227.250	160
26	L	20000	00	21	00.5	15	68.59	107.18	122.180	137.180	160
27	L	10000	01	47	55.73	20	166.99	293.95	313.950	333.950	160
28	L	6000	00	40	36.41	30	50.44	40.87	70.870	100.870	160
29	L	5000	01	04	30.39	40	66.91	53.82	93.820	133.820	160
30	R	2300	03	37	47.46	70	107.87	75.69	145.690	215.690	160
31	L	1700	09	56	22.04	130	212.76	164.71	294.710	424.710	160
32	L	600	10	39	22.58	110	110.52	0.58	110.580	220.580	105
33	R	5000	01	04	46.72	40	67.11	54.22	94.220	134.220	160
34	R	2500	06	07	12.77	65	166.15	202.04	267.040	332.040	160
35	L	5000	02	31	20.17	40	130.07	180.11	220.110	260.110	160
36	R	10000	00	28	44.23	20	51.80	63.59	83.590	103.590	160
37	R	2000	05	14	14.61	80	31.46	102.79	182.790	262.790	160
38	L	1500	13	18	44.69	120	234.99	228.31	348.310	468.310	160
39	R	2700	04	21	29.56	60	132.74	145.37	205.370	265.370	160
40	L	2500	04	31	59.17	65	131.45	132.78	197.780	262.780	160
41	L	2200	10	18	52.40	75	236.07	321.05	396.050	471.050	160
42	L	1200	09	07	58.8	130	160.89	61.22	191.220	321.220	150
43	L	600	15	40	59.76	110	137.23	54.08	164.080	274.080	105
44	L	1800	15	51	31.31	95	298.24	403.21	498.210	593.210	160
45	R	1000	11	39	56.71	115	159.71	88.54	203.540	318.540	135
46	L	1500	05	43	08.88	120	134.94	29.71	149.710	269.710	160
47	L	900	11	39	50.26	115	149.49	68.14	183.140	298.140	130
48	R	6000	04	25	23.70	30	246.72	433.20	463.200	493.200	160
49	R	1800	07	06	49.02	95	159.36	128.47	223.470	318.470	160
50	L	1800	05	15	46.42	95	130.24	70.33	165.330	260.330	160
51	R	2500	02	55	05.45	65	96.18	62.33	127.330	192.330	160
52	R	2000	07	01	29.90	80	162.75	165.18	245.180	325.180	160
53	L	1800	05	00	0.88	95	126.07	62.02	157.020	252.020	160
54	R	1500	07	09	25.88	120	153.73	67.17	187.170	307.170	160
55	L	500	31	26	21.98	110	195.25	162.89	272.890	382.890	95
56	R	500	45	45	47.35	110	265.68	289.27	399.270	509.270	95
57	L	500	20	17	50.28	110	144.69	66.90	176.900	286.900	95
58	L	3500	02	17	34.06	50	90.04	90.06	140.060	190.060	160
59	R	2000	05	24	54.49	80	134.59	109.02	189.020	269.020	160
60	L	700	16	15	32.76	105	152.56	93.60	198.600	303.600	115
61	R	1000	06	42	24.52	115	116.13	1.99	116.990	231.990	135
62	L	10000	01	09	06	20	111.06	182.12	202.120	222.120	160

63	R	2000	06	33	29.55	80	154.57	148.87	228.870	308.870	160
64	R	10000	03	43	41.45	20	335.46	630.69	650.690	670.690	160
65	L	2000	07	50	20.81	80	177.04	193.63	273.630	353.630	160
66	L	1000	15	30	09.56	115	193.69	155.51	270.510	385.510	135
67	R	3000	22	17	18.33	55	618.49	1112.02	1167.020	1222.020	160
68	L	1000	51	01	43.05	115	535.05	775.55	890.550	1005.550	135
69	R	7000	04	03	13.81	25	260.24	470.27	495.270	520.270	160
70	R	800	13	29	06.29	100	144.42	87.87	187.870	287.870	120
71	R	1500	05	34	08.72	120	132.88	25.57	145.570	265.570	160
72	L	700	34	31	07.45	105	269.88	316.03	421.030	526.030	115
73	R	900	22	33	45.89	115	236.89	238.91	353.910	468.910	130
74	R	2000	03	57	09.57	80	109.0	57.97	137.970	217.970	160
75	L	1800	04	06	01.31	95	111.94	33.81	128.810	223.810	160
76	L	2000	04	42	02.29	80	122.09	84.08	164.080	244.080	160
77	R	2000	04	39	10.55	80	121.24	82.38	162.380	242.380	160
78	R	1000	14	00	40.69	115	180.24	129.13	244.130	359.130	135
79	L	500	26	50	19.77	110	173.78	122.74	232.740	342.740	95
80	R	1500	10	48	30.28	120	201.83	162.76	282.760	402.760	160

Table 6-10 : Statement of Horizontal Curves (Spur Line)

Statement of Horizontal Curves (Spur Line)											
Curve No.	Direction	Radius	Deflection Angle			Transition Length	Tangent Length	Arc Length	Curve Length	Total Curve Length (M)	Maximum Permissible Speed (KMPH)
			D	M	S						
1	R	500	27	53	52.46	110	179.45	133.23	243.23	353.23	95
2	R	500	35	34	35.63	110	215.75	200.24	310.24	420.24	95
3	R	500	25	20	43	110	167.66	110.96	220.96	330.96	95
4	L	1500	07	51	18.47	120	163.01	85.61	205.61	325.61	160
5	R	1500	09	16	26.83	120	181.70	122.76	242.76	362.76	160
6	R	10000	01	21	50.73	25	131.55	213.08	238.08	263.08	160
7	L	2500	03	45	47.20	65	114.63	99.19	164.19	229.19	160

6.7.5. Track Centres

We propose a track centre distance of 4290 mms. This is based on the UIC practice for high speed trains, where the track centre distance is kept as 4000 mm for speeds upto 200kmph. The widest coaches in the UIC standard is 3380 mm. This leaves a distance of 620 mm between two adjacent trains. Keeping the same distance of 620 mm, for the RRTS coach of 3670 mm, the track centre works out to 4290 mm. However, this is suitable for tangent track only. On curves, the track centre distance has to be increased suitably in accordance with the Indian Railway SOD.

6.7.6. Rails

It is proposed to have continuous welded rails for the RRTS. CWR has the following advantages over conventional fish plated track:

- It ensures better safety since there is no possibility of fish plates opening or being tampered

- It provides more riding comfort with less noise and vibrations.
- It requires less maintenance

While the CWR track can be welded into a single rail from station to station, the current practice is to have switch expansion joints at regular intervals, in order to determine if there are any thermal stresses built up and relieve the same without having to cut the rails. For the RRTS it is recommended that the SEJs should be at 2 kms intervals since this provides the ideal length of the rail which can be taken up for de-stressing without taking very long possessions.

The rails should be welded by flash butt welding, which can be done easily nowadays by mobile welding plants. Thermit welding should be used only where flash butt welding is not possible for some reason.

The rail is recommended to be UIC 60 head hardened rails conforming to grade 1080 as per Indian railway Specification IRS T-12-2009 with elastic fastening at 60 cms apart on the viaduct and in tunnels. In depots, 60 Kg rail with 90 UTS can be used with spacing of 65 cms for fastenings.

6.7.7. Track Structure

The RRTS track will be subjected to intensive use with little time for day to day maintenance. Therefore the track structure should be long lasting, require little maintenance, be safe and reliable and give a comfortable ride.

There are two options for the track structure. Conventional ballasted track and option of ballastless track. Advantages and disadvantages of the two track form types are discussed and comparisons made between the two.

6.7.7.1 Application of Currently Available Ballastless Track Systems to RRTS

Most of the international ballastless track systems are designed for 1,435mm track gauge. Many of these have been assessed however for their adaptability to the proposed 1,676mm track gauge on the RRTS Delhi-Ghaziabad-Meerut railway.

The Sonneville LVT system does not incorporate a fixed integral gauge tie and so it is reasonable to assume that this can be readily adapted to suit virtually any of the track gauges between say 1,067mm and 1,676mm, commonly used around the world. There are two other systems similar to the Sonneville LVT (based on the principle of rail blocks cast in concrete, in-situ) – ‘EBS by ‘Edilon-Sedra’ and ‘CDM-BS’ by ‘CDM’. These however have not been installed extensively, and certainly not proven in service in main line railways similar to RRTS, and so would not be recommended.

Direct enquiries have been made with Max Bögl and A Porr AG and they have both advised that their systems can be adapted for most track gauges, specifically for the Indian railway gauge of 1,676mm. Responses from Rheda and Zublin have not been received however it would not be unreasonable to assume that both would be positive to the opportunity to supply their systems for the RRTS by adapting their products to suit 1,676mm track gauge.

The Railtech Stedef and Sateba systems comprise cast-in twin block sleepers, not dissimilar to but arguably less specialised than the Rheda system, since both have their origins in conventional ballasted track whereas Rheda is exclusively a

ballastless system. It may be therefore be assumed, that these two systems could also be used on RRTS provided their off-the-shelf sleepers could be adapted for the wider gauge.

Regarding the proposed vertical alignment of the RRTS, all the aforementioned ballastless track systems are capable of being installed on at-grade sections, on elevated parts of the route, or in tunnel. Structural concrete decks in elevated sections, and the concrete inverts in tunnels, in fact lend themselves to concrete trackbeds and so the ballastless systems are clearly suited, and preferred for these applications.

On the basis of the above discussions, it is proposed that plinth type ballastless track with RCC derailment guards integrated with the plinths be provided on the viaducts. To place ballast on a viaduct structure would entail a super imposed dead load which would not only result in a larger structure but would require greater maintenance. Accordingly ballastless track system is proposed for the via duct. Further, it is proposed to adopt “Vossloh-336 fastening system on both type of ballast less track structure with a base plate to base plate spacing of 60 cm on viaduct. Most of the components of Vossloh-336 fastening system are now indigenously available.

In the underground section, similar track structure as on viaducts is proposed with Vossloh-336 fastening system. Spacing of base plate will remain the same but on slabs instead of two separate longitudinal beams.

In depots, the track will be ballastless as well as ballasted. Ballastless track in Depot may be of the following type:

- Discretely supported on concrete/steel pedestal for inspection lines.
- Embedded rail type inside the workshop.
- Plinth type for washing plant type.

Ballasted track in depots will be provided at other than washing and inspection lines. This will be of PSC sleepers 60kg rail with elastic fastening system. Spacing of sleepers on those tracks can be 65 cm from centre of sleeper to centre of adjacent sleeper.

6.7.8. Track Fittings

Rail fasteners can be of conventional type with elastic fastenings which are commonly used on Indian Railways track, or direct fastening of Track to fixed infrastructure. The conventional type of elastic fastenings which are commonly used on Indian Railways track, have their limitations. Firstly, the rail clips with inserts of PSC-sleepers can be removed from track very easily, and so are prone to theft and thus compromise on safety. These clips can also break due to sudden variation of temperature in the area. Their elasticity is diminished slowly on track resulting loss of toe load and it comes out from sleepers due vibrations of train movement. This type of fitting requires constant watch by P Way staff everyday.

The direct fastening method is commonly used on structures where it would be problematic to install ballast(like elevated viaducts), or be difficult to clean and maintain (like tunnels) or where there are structural issues. It is also used where tight clearances to structures demand minimal movement of the line and level of the rail head.

It is recommended to use Vossloh – 336 fastening system on the ballstless track of the RRTS as this system has proved itself in Indian conditions. This system is found to be efficient as it is directly fixed on plinth of the track by iron base plate, rubber pads and elastic Vossloh 336 type fastening by means of bolts through pre-cast holes. These can be tightened in such a manner that it does not become loose due to vibrations of wheels. Moreover, a spring type arrangement is there, so that clips are firmly fixed on the rail foot all the time.

6.8 Signalling

The modern signaling system has been proposed for the RRTS to manage short headways and meeting other critical requirements.

6.8.1. Possible Options

Based on the analysis of the alternatives, potential option could be ECTS level 2 signalling system; with continuous track to train communications and the facility to overlay ATO at a later stage. ETCS Level 2 provides a continuous speed supervision system, which also protects against overrunning the Movement Authorities (MA). Data transmission is achieved by continuous radio transmission (GSM-R). MAs are generated trackside and are transmitted to the train via GSM-R. For some functions, the radio transmission requires complementing by spot transmission (Eurobalise). The detection of trains is achieved by track-based equipment, usually track-circuits or axle counters. The trackside Radio Block Centre (RBC) which provides the information to the trains recognises each train individually by the ETCS identity of its relevant ETCS on-board equipment. Signalling information is communicated to the driver by equipment in the driving cab and, optionally, by the lineside signals. However, lineside signals may be removed if not required due to the mixed traffic on the line or for fall-back reasons.

An alternative option would be to use the French TVM system, which was originally developed for high speed operation. This system has not been used before on a solely suburban railway and the supplier would have to reconfigure the system to achieve the required headways.

The other system which could provide similar functionality is Continuous Automatic Train Control System (CATC) that is already in use by several railways and is proven. This is presently deployed on Delhi Metro and can provide viable alternative in case of issue in radio frequency availability.

6.8.2. Proposed Signalling System for RRTS

ERTMS 2 requires continuous radio based communication between the control and the driver's cab. Use of radio as media for continuous track to train communication may be an area of concern for the RRTS due to the scarcity of radio frequency as well as cost. Signalling system providers have also used open frequency with some safety arrangements to protect signalling data through software logic and hardware keys but performance results of such signalling system is yet to be established. This limitation is not observed in CATC signalling option.

Considering the likely difficulty in getting the required radio frequency from the government, it was decided to use Continuous Automatic Train Control System of signalling for the RRTS at present stage. At the time of procurement, the review of other latest signalling technology could be undertaken and possibility of adopting latest communication based signal systems could be explored.

CATC provides a high level of safety with train running at close headway ensuring continuous safe train separation. CATC is capable of achieving functional, operational and safety requirements almost similar to ERTMS level 2. The only difference is that continuous communication between trackside equipments and train is through track using coded Audio Frequency Track Circuits, instead of through radio.

6.8.3. CATC System

The CATC comprises an Automatic Train Protection (ATP), an Automatic Train Supervision (ATS), an Automatic Train Operation (ATO) and a Computer Based Interlocking (CBI).

The CATC is controlled from the Operations Control Centre (OCC) in normal circumstances. During periods that the OCC is unavailable, the supervision of the CATC shall automatically transfers to the Local Control Operator work-stations provided in each station.

The signalling shall support a maximum line speed of 160 km/hour in Automatic Mode in either Normal or Reverse direction over the same track and shall have facilities for speed restrictions to be imposed on sections of track determined by the alignment design criteria. The speed restriction details shall be transmitted to trains in a fail-safe manner so that the trains are driven and supervised in compliance with those speed restrictions.

6.8.3.1 Automatic Train Protection (ATP)

The ATP system is a vital ‘fail safe’ component and is ‘target speed’ and ‘target distance’ based conforming to the safety and reliability standards. This vital system maintains the safety of train operation including separation of trains, enforcement of speed restriction, and safe operations through interlocking. The transmission from Track to Train shall be continuous through Coded Audio Frequency Track Circuits (AFTC). All the functions under ATP shall be Vital Functions.

6.8.3.2 Automatic Train Supervision (ATS)

This System directs Train Operations to provide Scheduled service under normal conditions and the best service possible under adverse conditions. The ATS shall provide non-vital functions to supervise, control and optimise the train movements. It shall initiate route requests at interlocking, but the ATP and interlocking logic shall provide for the safe movement of trains through the interlocking. It exchanges requisite messages with external Sub-systems such as CBI, ATC, Master Clock, PIDS / PAS, Train Radio, and NP-SCADA etc.

6.8.3.3 Automatic Train Operation (ATO)

While during initial years of operation, fully automatic train operations are not envisaged, however system shall have provision to upgrade to ATO if business case justifies the additional cost

Functions under Automatic Train Operation (ATO) System shall include Automatic Control of Train running from Station to Station, while remaining within the Safety

Envelope calculated by the ATP. The Train Speed, Acceleration / Deceleration and Braking shall be automatically controlled, without the Driver's intervention, preventing unnecessary Braking, Stopping and Starting. It should include automatic opening of train doors on correct side.

6.8.3.4 Interlocking System

The Interlocking System shall be Computer based. The Computer Based Interlocking system shall be to provide a very high level of availability and safety for route interlocking and controlling and monitoring the inputs/outputs of all equipment installed along the wayside in fail-safe manner. The Main function of Interlocking System shall be to provide the Control and Indication functions and also support all the feasible Train movements in the Yard. The CBI shall be based on Entry-Exit System and shall provide bi-directional working. The System shall interface with CATC Systems.

6.8.3.5 Track Circuit:

To detect train in a particular portion of track, a circuit is designed in such a way that rails in that portion of track are the part of track circuit. Joint less Coded Audio Frequency Track Circuits (AFTC) shall be used for Train detection purposes. The information of occupied/vacant track circuit is transmitted to the interlocking system. Other important function of AFTC is continuous Track to train communication for ATP, when Track circuit is occupied.

6.9 Communications

Communication System provides the necessary subsystems to support the total operation requirements of a rail system. The Communication System has to be a highly resilient system commensurate with the operational philosophy proposed for the RRTS.

The options for the telecommunications systems are split into three sections: Network Infrastructure, Network Systems and Stand Alone Systems.

6.9.1. Proposed System

The options described in the following pages have been made based on cost, ease of maintenance and suitability of integrating into the network.

6.9.1.1 Control Centre: High Degree of Centralisation

Due to it being the most cost effective way of managing assets and infrastructure the chosen option is to centralise everything where possible. Measures must be taken to minimise the effects of disruptions.

This involves putting all telecoms network management equipment in one building. The ideal place for this building would be the main control centre for the route. There would be a strong requirement for telecoms, signalling and power supply services at this centre regardless and efficiencies would be gained from locating them together. A typical image of OCC is shown in figure 6-6.

Figure 6-6: Control Centre

6.9.1.2 Transmission Backbone: Gigabit Ethernet

This recommended option requires an Ethernet switch installed at each station and depot. They would be connected by fibre optic cables along the railway in a ring topology. This would allow all services to be run from the control centre with the minimum other of equipment on the trackside and at the stations. This option is far cheaper than the alternatives.

6.9.1.3 Mobile Radio Communication

After comparison of proposed systems for RRTS it was decided to adopt Mobile Radio Communication with TETRA standards.

The Terrestrial Trunked Radio (TETRA) featuring high reliability, fast connection and flexible call configuration shall be used for mobile radio communication. It shall provide full-duplex, two-way radio communication in all areas (public and non public) of the OCC, stations, substations, depot, track and tunnel, entrance ways, link ways, including those with interfacing MRT stations and over the entire Line.

RF site survey shall be carried out during design stage to ensure adequate coverage. Radio channels shall be assigned for different functions, including:

- Train regulation
- Train PA broadcast
- Depot operation
- Operating and maintenance

In underground stations and tunnels where the external radio signals of the Police Force, Emergency Services and commercial mobile phones cannot penetrate, these signals shall also be relayed into the RF infrastructure of the Radio System so that their communications can be maintained. To ensure adequate coverage in underground section adequate base stations fed through bidirectional amplifiers and Leaky cables shall be provided in underground section.

6.9.1.4 Station Systems: PIS, PA/VA, PHPs and LAN

These systems are used in stations across Europe. By using a unified network for all applications, data and voice cabling costs are reduced. User access to multiple systems such as Access Control, CCTV, Fire, and Building Control is simplified

through a single common interface that provides fast access to detailed information. Training costs are also significantly reduced since each operator only needs to be trained on a single system. Hence recommended.

6.9.1.5 CCTV: Targeted Coverage

The CCTV system is ultimately there to help protect staff, customers and visitors to the stations. They are used in station environments around the world.

Areas to be recorded would be determined by a risk assessment of each station but would include entry and exit points where people must pass through and areas where people are likely to congregate. Although this option is initially more expensive than not having any CCTV system, costs will be saved during the operation of the railway. Rail staff can be directed to where they are most needed. Hence provision of CCTV recommended.

6.9.1.6 Train Dispatch: DOO CCTV with On-board Cameras and Monitors

This will allow the driver to assess the platform train interface from inside the cab. This will reduce station dwell times and improve safety. Typical image of Driver's Cab CCTV monitors is shown in figure 6-7.

Figure 6-7: Driver's Cab CCTV Monitors

6.9.1.7 Blue Light Station (BLS)

BLS shall be provided at cross passages, crossover tracks, headwall and tailwall of each platform, emergency access points, centre track, overrun and along the tracks appropriately spaced, etc. and in accordance with NFPA 130. The voice communication device supplied within the BLS shall be a ruggedised telephone connected to the OCC as a direct line.

6.9.1.8 Power Distribution System

Power distribution system for the Communication System equipment shall include the power distribution to all peripheral communication equipments including those

installed external to the equipment rooms. Associated battery backup systems for at least 3 hours of backup operation for Communication System equipment shall be provided.

6.10 Automatic Fare Collection System

The RRTS will handle a large number of passengers daily and ticketing & fare collection will be an important factor in the efficient and proper operation of the system. To manage the fare collection, the ticketing system must be simple, easy to use and operate, require few accounting facilities and be flexible. It should also minimise the manpower required to operate the system. Manual ticket issue and fare collection cannot cope with the heavy rush of passengers using the RRTS and will cause huge delays in the train running. Computerized automatic fare collection system therefore has to be used on the RRTS.

6.10.1. AFC System

An Automatic Fare Collection System (AFCS) is a method of providing automated revenue management. An AFCS facilitates the purchase of pre-paid tickets that can be used to permit access to /from various transport modes through the use of electronic systems and thus eliminating all human error and confrontation. An AFCS also provides valuable information for the management of the transport system.

For an AFCS to be successful it needs to provide the following to the travelling public. Easy to understand and use machines & gates and technology, Transactions completed quickly and reliably done, Appropriate choice of ticket types- and payment methods, Allow easy transfers between transport modes and different transport providers, access to purchasing tickets and topping up value storage cards from remote locations (Internet, mobile phone, shops, etc). Efficient and adaptable to changing needs an AFCS also helps to enforce the safety and security policy of the transport system.

In order to cater for current and future fare structures the AFCS should be suitable for the commonly used stage based fare structure but also for other possible options such as flat rate and time based (including peak and off peak time segments).

The AFCS shall be compatible with the system already being developed by the National Capital Region for a common Smart Card for all modes of transport in the NCR.

6.10.2. Description of AFCS

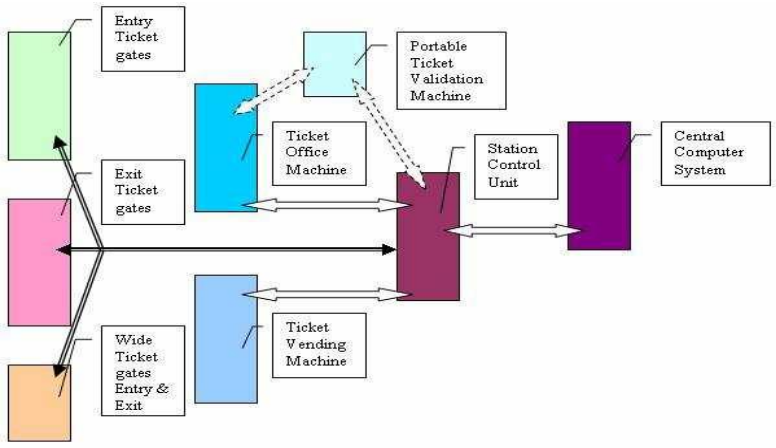
An AFC system is made up of the following 6 key components;

1) Central Support System (CSS): This is the back bone of the system and manages the flow of data to/from the optic fibre interconnections as well as being a powerful tool for system management and statistical analysis. The Central Support System typically consists of computers and software at each station (station control unit) and also at a central data collection point (Central Computer System).
2) Optic fibre network and data management system. This rapidly transfers data from one part of the AFCS to another.
3) Automatic Ticket Gates (ATG): These process ticket validity and permit access to/from the transport system.

4) Ticket Vending Machines (TVM): The TVM provides a means for the purchase and issuing of tickets and topping up of smart cards.
5) Ticket Office Machines (TOM): The TOM is used by a staff member to transact the purchase and issuing of tickets, free passes and none standard transactions.
6) Ticket and fare storage media including the storage of travel journey information.

These key components and they interrelationships are depicted in figure below:

Figure 6-8: AFCS Schematic



6.10.3. AFC Equipment Requirement

For the RRTS, the proposed ticketing system shall be Automatic Fare Collection with Contactless Smart Token/ Cards. Equipments for the system shall be provided at each station, Counter/Booking office at convenient locations and will be connected to a local area network with a computer in the station Master's room. The main features of the system shall be as given in table 6-11.

Table 6-11: Requirements of AFC

Item	Requirement
Ticket	Contactless Smart Token – For single journey. They shall have stored value amount for a particular journey. Tokens will be captured at the exit gate. Contactless Smart Card – For multiple journeys. Can be recharged at stations or remotely.
Gates	Retractible flap type, computer controlled automatic gates at entry and exit. The gates will be of following types: Entry/Exit Reversible – can be set to entry or exit Handicapped – wide reversible gate for disabled people.
Station computer, Central computer and AFC net work	The AFC equipments shall be connected in a LAN with a station server controlling the activities of all the machines. These station servers will be linked to the central computer situated in the OCC through the communication channels. The centralized control of the system shall provide real time

Item	Requirement
	data of earnings, passenger flow analysis, blacklisting of specified cards etc.
Ticketing machine	Manned Ticket office machine shall be installed in the stations for selling cards/ tokens to the passengers. There will also be Passenger Operated Machines at the station for automatic ticket vending.
Ticket reader and portable ticket decoder.	A ticket reader shall be installed near the ticket vending machine for passengers to check information stored in the token / cards.
UPS (uninterrupted power at stations as well as for OCC).	The UPS of the S&T system will be utilized for emergency power supply to the AFCS.

6.11 Electric Power Supply

The RRTS requires electrical power for operation of the trains, running the station services like lighting, lifts, escalators, operating the signal & telecommunication system, depots and other infrastructure. The most important requirement is the traction power supply. The different types of traction power supply, their advantages and disadvantages are discussed below. Following this, a suitable power supply system for the RRTS is selected and described.

6.11.1. Proposed Electrification System

Two types of system namely 25kV classic and 2X25 kV systems were evaluated. 25 kV AC. Classic System Overhead Line has been recommended for Delhi – Ghaziabad – Meerut line. We recommend this system as being best suited to the requirements of the corridor, as described below.

25kV AC. 50 Hz traction power supply overhead line is now the standard voltage in India with over 80% of the electrified network in this form and is the most suited to this type of railway system, because this has a number of benefits including system familiarity (construction and maintenance); availability of spare parts; and usage worldwide on high speed railways. The 25 kV AC. system of traction emerged as an economical system of electrification as a result of extensive research and trials in Europe.

The 2x25kV (AT) system, offers increased power availability to supply heavier demands, an increase in the distance between catenary feeder substations, or a combination of these benefits.

The 2x25kV system could offer some cost saving by reducing the number of feeder stations, which are high value items. This saving may not be fully realised on the Delhi – Ghaziabad – Meerut Corridor as there must be sufficient spare capacity in the event of a major substation or supply point failure - that is, it should be possible to keep the train service operating even if one substation is completely out of service. The saving of substation cost will not be more than one considering route length and minimum requirement of substations. Furthermore, the 2x25kV system needs increased space to maintain clearance to the along track 25kV feeder, which is likely to increase costs in tunnels and other confined spaces.

At this stage we believe the 2x25kV system will not offer any significant saving over the classic system.

6.11.2. Traction Power Requirement

The RRTS will have 25KV, 50 cps power supply for traction. The power will be supplied to the rolling stock through a flexible catenary in elevated sections and a rigid catenary in underground sections. Sectioning posts and sub sectioning posts will be located at appropriate intervals. Suitable measures will be incorporated to mitigate the effects of EMI and EMC caused by the 25 KV single phase power supply.

6.11.2.1 Total Power Requirement for the RRTS

Based on the various assumptions, the total power requirement for the RRTS has been calculated for the years 2016, 2021, 2031 and 2041. The requirement has been split up into the following sections, which is based on the train running pattern.

- Sarai Kale Khan to Guldhar
- Guldhar to Meerut South
- Meerut South to Shatabdi Nagar
- Shatabdi Nagar to Modipuram
- Shatabdi Nagar to Shashtri Nagar

The total power requirement for sections is given in Table 6.12. These show the traction as well as the auxiliary power requirements for the years.

Table 6:12 : Power Requirement

SUMMARY OF POWER REQUIREMENT in MVA						
Section		**Year 2016**	**Year 2021**	**Year 2031**	**Year 2041**	
Modipuram – Shatabdi Nagar	Traction Power Required	6.07	6.38	8.79	9.10	MVA
	Auxiliary Power Required	11.94	12.99	14.32	15.50	MVA
	Total Power Required	18.01	19.37	23.11	24.60	MVA
Shatabdi Nagar - Shashtri Nagar	Traction Power Required	2.66	2.66	3.99	3.99	MVA
	Auxiliary Power Required	6.10	6.47	8.39	8.82	MVA
	Total Power Required	8.76	9.13	12.38	12.82	MVA
Shatabdi Nagar – Meerut South	Traction Power Required	2.91	2.91	4.37	4.37	MVA
	Auxiliary Power Required	1.31	1.37	1.90	2.02	MVA
	Total Power Required	4.22	4.29	6.27	6.39	MVA
Meerut South – Guldhar	Traction Power Required	16.21	16.21	24.32	24.32	MVA
	Auxiliary Power Required	2.96	3.21	3.52	4.01	MVA
	Total Power Required	19.18	19.42	27.84	28.33	MVA
Guldhar – Sarai Kale Khan	Traction Power Required	13.48	21.06	25.27	31.58	MVA
	Auxiliary Power Required	11.88	12.69	16.07	17.06	MVA

SUMMARY OF POWER REQUIREMENT in MVA						
Section		**Year 2016**	**Year 2021**	**Year 2031**	**Year 2041**	
	Total Power Required	25.36	33.74	41.34	48.65	MVA
	Total Traction Load	41.33	49.22	66.74	73.37	MVA
	Total Auxiliary Load	34.20	36.73	44.21	47.42	MVA
	Grand Total	75.53	85.95	110.95	120.78	MVA

6.11.3.Sources of Power Supply

6.11.3.1 Location of RSS and GSS

To cater to the traction and auxiliary loads, it is considered necessary to have 4 Receiving Sub Stations for the RRTS, to feed the 90 km long corridor.

The feasibility of getting the required power from the grid sub stations was ascertained through discussions with the authorities of Delhi Transco Limited and UP Power Transmission Corporation Limited. They have confirmed that the following sources are available for the power supply (Table 6-13).

Table 6-13: Receiving sub stations

S. No.	Receiving Sub Station (RSS)	Supply from Grid Sub Station (GSS)
1	Shatabdi Nagar (Jagran Chowk)	220 KV SS at Shatabdinagar from UPPTCL
2	Muradnagar (NH 58)	400 KV SS at Muradnagar II from UPPTCL
3	Ghaziabad (NH 58)	400 KV SS at from UPPTCL
4	Sahibabad (NH 58)	400 KV SS at Indirapuram from UPPTCL
5	Delhi (Sanjay Lake)	220/33KV SS at Anand Vihar from Delhi TRANSCO or 132/66KV SS at Akshardham from BSES Yamuna

The preferred locations of the Receiving Sub Stations are at Shatabdi Nagar, Muradnagar, Ghaziabad and Sanjay Park. Sahibabad has been selected as an alternative in case Delhi is unable to supply the required power. The Sahibabad RSS will in that case feed the Anand Vihar-Sarai Kale Khan section. Discussions with Delhi Transco had revealed that they are having some problem in acquiring land for their Anand Vihar Grid sub station and therefore Sahibabad has been kept as a standby.

6.11.3.2 Receiving Sub Station Capacities

Based on conceptual design and power requirement calculations, the broad capacities of the Receiving Sub Stations have been assessed as under:

i.) RSS-1 (40 MW) in Delhi state at Sanjay Lake or
ii.) RSS-1 (42 MW) in U.P. state at Sahibabad
iii.) RSS-2 (40MW) in U.P. state near Ghaziabad
iv.) RSS-3 (40MW) in U.P. state at Murad Nagar
v.) RSS-4 (40MW) in U.P. state at Meerut

6.11.4. Supervisory Control and Data Acquisition (SCADA) System

The entire system of power supply (receiving, traction and auxiliary supply) shall be monitored and controlled from a centralized operation control center (OCC) through SCADA system.

6.11.5. Emergency Trip System (ETS)

In underground portion of the RRTS, Emergency Trip System (ETS) shall be provided. There will be a continuous ETS cable and the station platform ends and cross-passages shall have illuminated Emergency Trip Push Button switches. The ETS can be operated by passengers and RRTS staff in case of emergency situations to stop the train(s). Operation of ETS push button will result in tripping of relevant section of the OHE equipment as well as the section behind, with an alarm and indication to the OCC. ETS cable shall be fire rated for one hour at 5000 C.

6.12 Civil Engineering (Viaduct & Tunnel)

6.12.1. Viaduct Section

The main objective of this section is to present the techno-economical features of the various available options for the Viaduct Section for RRTS and recommend most beneficial option for the construction of Viaduct.

6.12.2. Choice of Superstructure

Following three options were studied wherein the casting operation are restricted to the Casting yard while at site only erection and launching operations are required thereby making the full standardization and mechanization of construction of superstructure possible. The Options are:

1) Precast Pos-tensioned Segmental Box Girder
2) Precast Pos-tensioned Segmental Single U girder
3) Precast Full span Pre-Tensioned Double U girder

The first two options are suitable for precast Post-tensioned segmental launching as due to cross-section size of these two options the weight of full span precast girders is very high which shall create difficulty in handling during erection. Typically for option-1 ie box section for a 37m span the weight shall be 550T to 600T and for option-2 ie single U Girder this shall be 400T to 450T for a 30m span. Also the width of Full span which is typically of the order of 11m shall create severe transportation problem in urban and semi urban situation as in case of RRTS alignment. In case of segmental launching in both options the segments are typically 3 m in length having a weight of 40T to 50T and can be easily transported if the length of segment is aligned in the width direction of Trailer.

The third option i.e. double U shaped girder is suitable for full span launching as the weight of one Part is approximately 180T for a span of 30 m and width is 5.6m. However this requires specially designed trailers and launching cranes/system.

6.12.3. Comparisons of Cross-section Shapes

As already discussed two Cross-section options involving segmental construction are investigated i.e. Box-section and Single U section. The specific advantages and disadvantages of using these are discussed below.

6.12.3.1 Precast Post-tensioned Segmental Box Girder

This option involves Segmental Launching of Box-Girder segments by a Gantry girder mounted on already erected superstructure and substructures. Most of the Delhi-Metro elevated section is constructed using this technique. The main advantages of this section are;

- Box is torsonally rigid and thereby efficient structural member.
- Possibility to use external pre-stressing cable for future strengthening and these cables are concealed inside the box, thereby not causing any visual intrusion
- No external Cross-Girder required as the diaphragm can be accommodated in internal opening of box at pier segment.
- Cheaper than the single U section

6.12.3.2 Precast Post-tensioned Segmental Single U girder

The main advantages for this type of structural configuration of superstructure are:

- Built in sound barrier.
- Built in cable support and system function.
- Possibility to lower the longitudinal profile by approximately 1m Compared to conventional design.
- Built in structural elements capable to maintain the trains on therequired bridge in case of derailment (a standard barrier design allow this)
- Built in maintenance and evacuation path on either side of the track.

The limitations of this section are:

- Inefficient structure sections
- Requires cross pre-stressing of pier segments
- At X-over locations the girders are to be connected at slab level hence changing of bearing at later stage becomes very difficult.
- Costly than Box girder.
- Design for U shaped girder for railway have been patented internationally and in India by SYSTRA and financial implications regarding use of this cross section are difficult to quantified.

6.12.3.3 Precast Full span Pre-Tensioned Double U girder

The main advantages for this type of structural configuration of superstructure are:

- No thickening of web or soffit required due to introduction of 2 more webs in the single U shape. Typical section is applicable to entire length. No adjustment required for changes in span length.
- Built in sound barrier.
- Built in cable support and system function.
- Possibility to lower the longitudinal profile by approximately 1m Compared to conventional design.
- Built in structural elements capable to maintain the trains on the bridge in case of derailment
- Built in maintenance and evacuation path on either side of the track.

The main limitations of this section are:

- At X-over locations the girders are to be connected at slab level hence changing of bearing at later stage becomes very difficult.

- Design for U shaped girder for railway have been patented internationally and in India by SYSTRA and financial issues regarding use are difficult to quantify.

6.12.4. Cost analysis of Three Options

The costing of three options for RRTS is done based on quantities derived after preliminary design of different element of three options. The comparison cost summary is presented below.

Table 6-14: Comparison of Cost

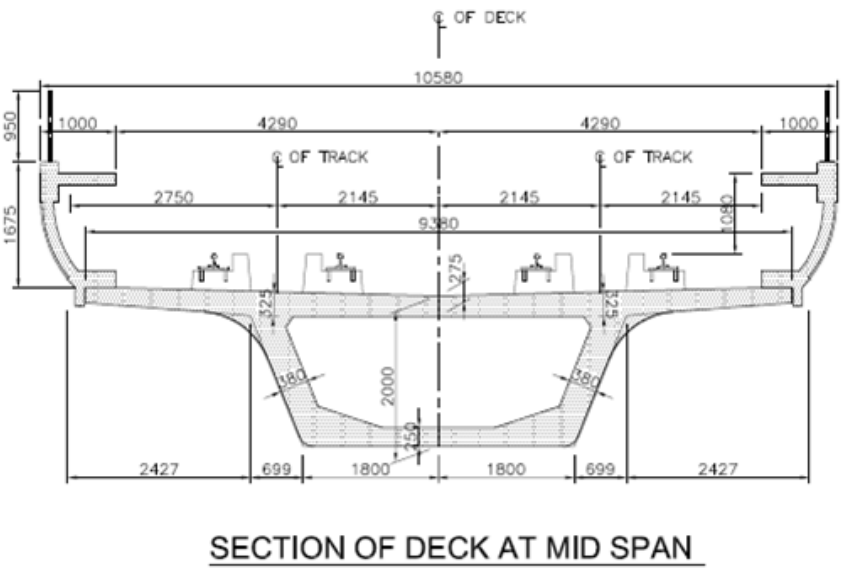
Substructure Type	Cost in Crores per Km		
	Option-1 (Box Girder)	Option-2 (Single U)	Option-3 (Double U)
Standard Height Pier Section	27.354	29.151	24.922
Portal Pier Section	39.424	39.927	34.872
Double Height Pier Section	31.786	33.368	28.643

It can be seen that in all three types of sections that will be encountered in RRTS viaduct the double U option is cheapest while single U option is costliest.

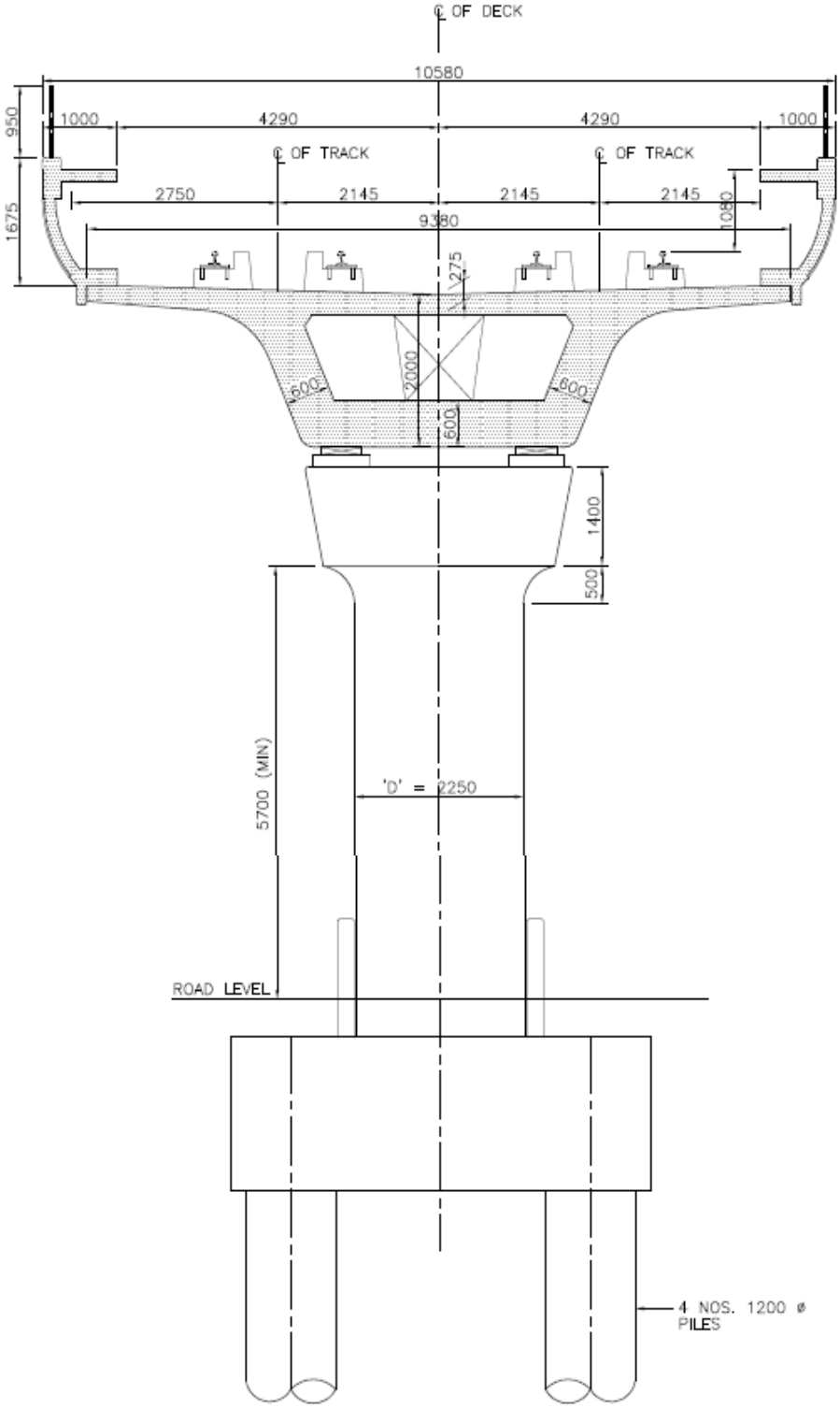
It is clear from above analysis that Box girder is costlier by 9.8% to 13.1% compared to Double U option for different types of sections and Single U girder is costlier by 14.5% to 17% than Double U option for different types of sections.

However, since U shaped girders have patent issues and its financial implications are not known, and cost difference of box girder is not significant (as compared to double U), hence, box type girders are proposed at this stage. The section of preferred viaduct is shown in figure 6-9.

Figure 6-9: Recommended Cross section of Viaduct



SECTION OF DECK AT MID SPAN



SECTION OF DECK AT END SPAN

6.12.5.Special Spans

The standard spans suffice the purpose for most of obligatory crossings except for three following location where special spans are required. These spans have been proposed with extra-dosesd option instead of balanced cantilever construction. Although the construction method of both are identical extra-dosed option is

preferred as it involves very less deck depth and are very elegant in appearance. The costing of both option is approximately same.

Table 6-15: Details of Special Spans

Ch From	Ch To	Span arrangement
36597.667	36792.667	75+120+75
46870.000	47016.000	56 +90 +56
56380.000	56545.000	65 +100 +65

6.12.6. Tunnel

In Meerut area the underground alignment starts after Shatabdi Nagar and continues towards Begumpul, passing through HRS Chowk where the underground HRS Chowk Station is there. After this, the alignment continues underground till Begumpul where the underground Begumpul Station is proposed. Beyond Begumpul the alignment rises to elevated section.

Another section of the underground alignment starts from Shatabdi Nagar and continues on the spur line till Hapur Road, where the underground Hapur Road station is there. It then rises up to the elevated Shashtri Nagar station.

In Delhi area, the underground section starts from Sarai Kale Khan terminus station and continues till the Anand Vihar, crossing under the Yamuna river on the way. At some locations, the alignment passes from elevated to underground and vice versa. This produces shallow location tunneling in some stretches and deeper tunnels at other locations. Also most of the tunnel lengths are falling beneath built up area. This necessitates careful selection of technology for tunnel construction.

6.12.7. Tunnel Systems and Geometry

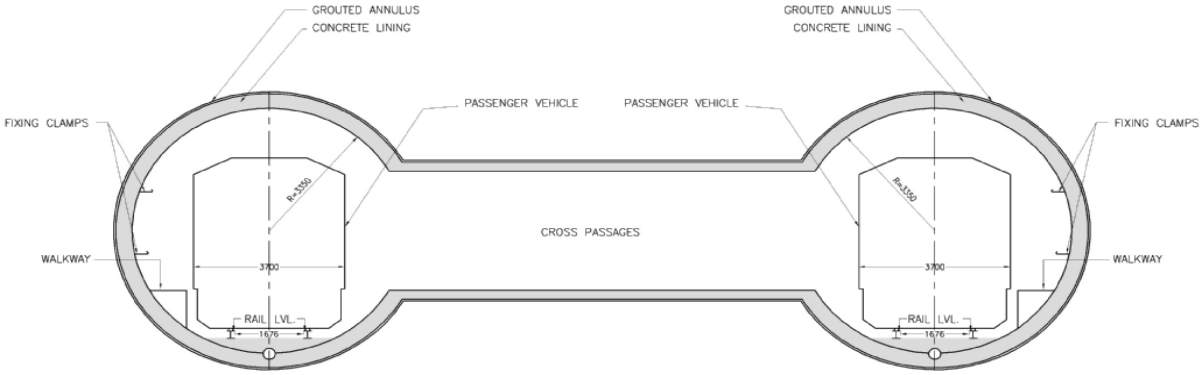
Twin bored single track tunnels are proposed for RRTS. Possibility of single bored double track tunnel also has been assessed and found difficult to construct in the project geology along with other considerations: Internal diameter of 6.7m has been worked out based on railway engineering, geotechnical and other urban tunnelling constrains (refer Figure 6-10).

Because of smaller diameter of twin tunnels saving in tunnel depth, low soil overburden is needed for soil stability. Due to saving in tunnel depth, stations will be located near the ground surface. So, their construction costs reduce. Since stations have peninsula like design and access structure to platform located on peninsula platform, station width decreases. This therefore, decreases station construction costs. More suitable ventilation and safety may be appreciated. From the viewpoint of safety, the second tunnel can be used for first aid purposes in construction duration.

The typical running tunnels cross sections for RRTS are circular. This section is deemed to meet the required railway standards in terms of structure gauge, kinematic envelope, service reserves and space for walkway

Construction of tunnel work will mostly be done by tunnel boring machine and cut-&-cover for the bored tunnels construction Earth Pressure Balance Machine (EPBM) or Slurry Shield TBM’s are recommended however these have to be attuned during the detailed design stage.

Figure 6-10: Tunnels cross sections at cross passages location



6.13 Alignment Design Proposals

The proposed alignment would have preferred cross sections of tunnel and viaducts as described earlier.

In the underground sections, twin bored tunnel section has been proposed. This will be applicable in most of the part between Sarai Kale Khan – Anand Vihar section and Meerut city alignment excluding some areas where cut and cover method is preferred.

The section after Anand Vihar till Meerut will be on viaduct. The standard viaduct (refer figure 6-11) will be adopted for most of the length except at Murad Nagar and Modi Nagar where elevated road is proposed along NH 58. At these locations double elevated viaducts are proposed. The proposed cross section of double elevated viaduct is shown in figure 6-12.

Figure 6-11: Standard Viaduct

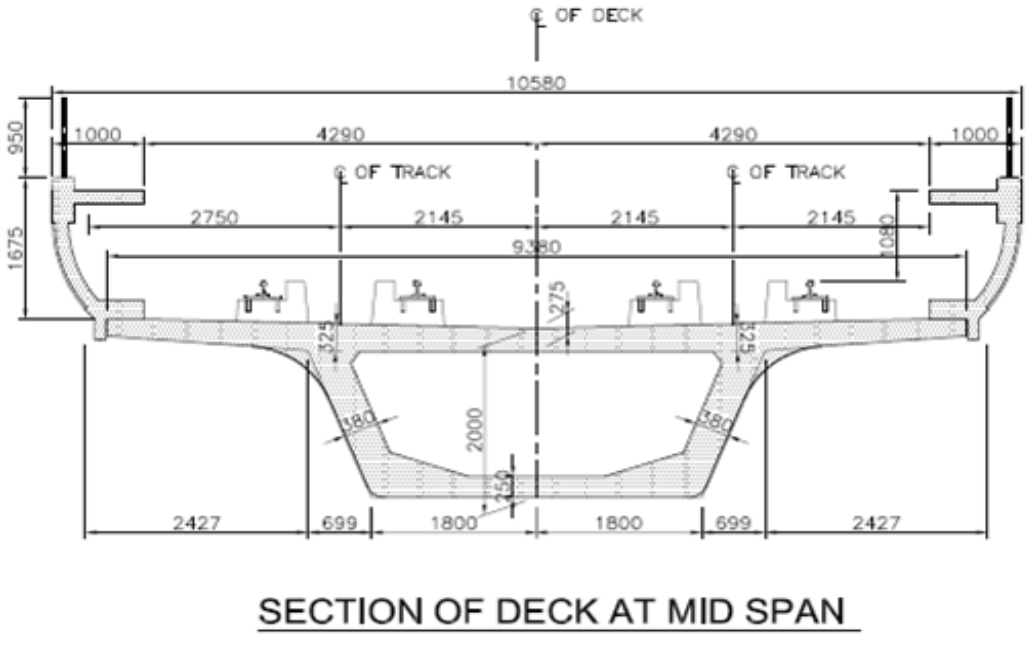
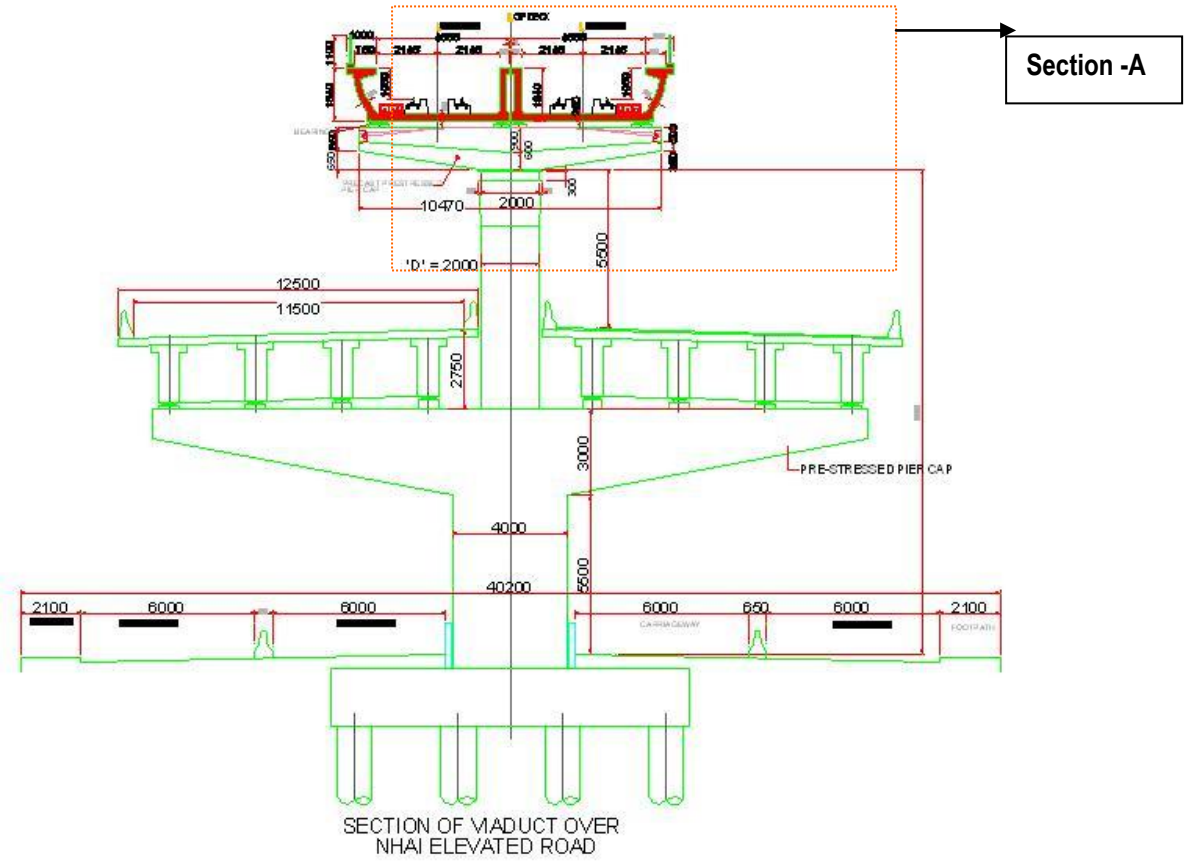


Figure 6-12: Double elevated Viaduct at Modi Nagar/ Murad Nagar



6.14 Operations and Service Delivery

The purpose of this Operation & Maintenance plan is to outline the preliminary provisions that will need to be made in order to enable the RRT system to function and operate effectively in compliance with the requirements of an approved Railway Safety Case.

6.14.1. Organisation

The Operator of the RRTS system will require an operations organisation with individuals having the roles and responsibilities well defined. The outlined structure will ensure all the major activities are assigned and communication lines and responsibilities are established.

6.14.2. Rolling Stock

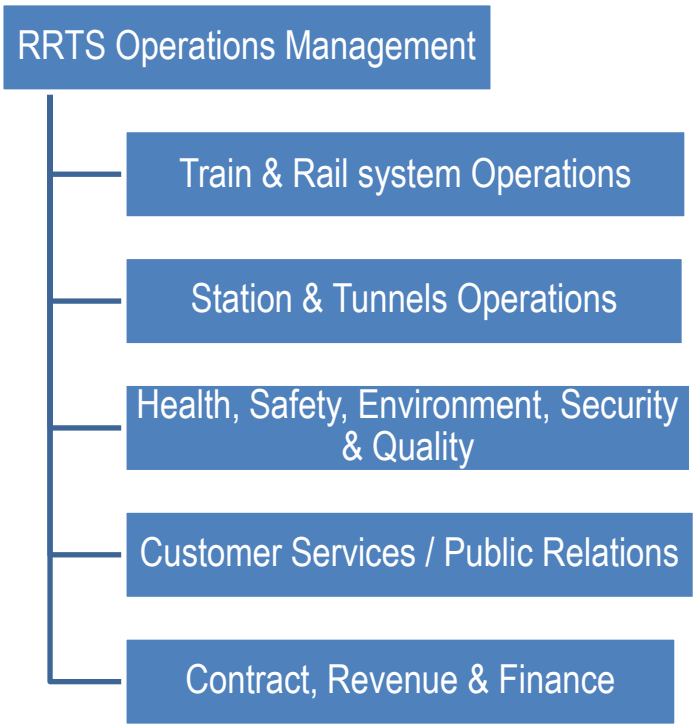
The trains for the RRTS Delhi – Meerut corridor will be operated and maintained by the SPV set up for implementing the RRTS or a suitable train operator appointed for this purpose. The operator will produce route timetables, working timetables, train maintenance schedules and route diagrams to meet the service demand and train maintenance requirements.

The operator will devise train driver diagrams and rosters so that adequate resources are made available to deliver the timetabled service. The operator will ensure train drivers are adequately trained and qualified to drive the trains, respond to alerts and

warnings given by the train and the taking of appropriate actions to ensure the train is safe.

The management of all issues to do with the running of the trains and the recovery of failed trains will be undertaken by the operator in conjunction with the managers and controllers of the rail systems. Operations organization chart is shown in figure 6-13.

Figure 6-13: Operations Organisation



6.14.3. OCC & BCC

The operation of the rail systems will be controlled from a central Operations Control Centre (OCC) located within the Modipuram Depot building. A Backup control centre (BCC) is proposed at Duhai Depot to maintain centralized train operation to operate trains in case of total OCC failure.

6.14.4. Signalling

The CATC signalling system will be controlled from workstations within the OCC for centralized train control. Train operation can be controlled through local workstations at stations in case of manual train operation requirement during failure or maintenance activities.

6.14.5. Telecommunications

Communications between the train and the signaller will be via TETRA radio. Communication between the signaller and other controllers and departments will be by telephone. All calls will be recorded.

6.14.6. Tracks

The tracks will be constantly monitored for wear and tear, defects and alignment so that the ride quality and safety of the line is maintained within established limits. Engineering controller at OCC will coordinate with train controllers at the OCC so that

appropriate train movement control measures can be put in place during maintenance and failures.

6.14.7. Overhead Line Equipment

The monitoring and operation of the HV and traction power and OHE systems will be undertaken by an Electrical Control room Operator (ECO) from a workstation with the OCC. The operator will have a SCADA facility which will be able to open and close circuit breakers and isolators to make sections of the system either energised or non-energised as needed or change the feeding arrangements when required. The ECO will control the issuing of electrical “permit to work” documents.

6.14.8. Tunnel / Enclosed Station Ventilation

The ventilation systems for the tunnels and the stations used for smoke and heat extraction to create a safe escape route for passengers evacuated from a train in the case of a fire will be operated from a workstation with the OCC. In conjunction with the ECO and the signaller a safe escape route will be established. The chief OCC controller will be responsible for coordinating all emergency services involvement.

6.14.9. Security

A security workstation within the OCC will provide monitoring and control of all security systems used on the Delhi – Meerut corridor. Where a person requires permission to enter a controlled access area then the Security controller will be responsible for granting such permissions. The security controller will monitor CCTV images of the stations and tunnels and observe for any intrusion or unauthorised access violation.

6.14.10. Fire and Life Safety

Fire alarms and the status of life safety systems will be monitored from a workstation with the OCC. The chief controller will respond to warning alarms and messages and involve the emergency services as necessary.

6.14.11. Traffic Controller (TC)

Each of the stations will be monitored locally from a workstation within the Station Operations Room with the station supervisor being responsible for monitoring and controlling key station equipment - lifts, escalators, ticket machines, ticket gates, security, station services (CIS, PA, lighting, cooling, etc.), fire alarms and the CCTV cameras. If an alarm or warning is not responded to within a preset time by the station supervisor then the alarm would be escalated to the CSC for appropriate action.

The TC has a key responsibility to ensure service information on Customer Information Systems (CIS) and announced on Public Address (PA) systems are up to date and correct.

If services are disrupted then the TC would advice the local station supervisors about announcements to be made and actions to be taken to reassure and control passengers. The TC will have access to all CCTV images of the stations.

6.14.12. Customer Services

The travelling public (passengers or customers) will be provided with the following key operational services to help them with their journey.

- Customer Information System (CIS)
- Public Address System (PA)

6.14.13. Stations

Each station will be provided with station entrances, an unpaid area with ticket machines and a ticket office, a ticket gate line, a paid area only accessible via the ticket gate line or authorised staff entrance ways which gives direct access/egress to the station platforms. Changes in levels will be facilitated by the use of stairs, escalators and lifts. Permanent signage will be well placed to facilitate clear orientation for passengers using the RRTS System.

Security guards will be present on all stations on a random basis and as directed by the CSC.

Any staff or contractors requiring access to the station outside of normal opening hours will contact the station supervisor or TC in advance to make arrangements. They will then be let in and out by a Security Guard who shall ensure that they register their presence on the station in the station visitor log book.

6.14.14. Staffing and Duties

All staff on duty within a station will carry a hand portable radio at all times to give constant communications to their peers and the TC.

In order to fully manage the evacuation of the station in an emergency, the operational staff, assisted by others where appropriate, will take charge of implementing established evacuation procedures.

The operational staffs that shall be on duty within each station during operational hours are:

- Station supervisor, generally based in the Station Operations Room, but attending to other station activities as required;
- Gate line attendant (one for each gate line);
- Platform attendant (one per platform)
- Roaming attendant, responding to operational and passenger needs as they arise, but also attending to other station activities as required.

Others who may be on the station and called upon to assist in emergency situations are:

- Contract cleaners;
- Maintenance personnel;
- Security Guards; and
- Visiting members of staff (management).

All station staff on duty will be having immediate contact to the Traffic Controller and local station supervisor by radio. In the event of an incident or fire alarm sounding, the nearest member of station staff will be directed to investigate. Depending on the outcome of the investigation, the positive alarm sounded procedure would be invoked or the team would be stood down and the alarm reset.
Incidents would be brought to the attention of the Traffic Controller by the station supervisor or the sounding of an alarm. In the event of an evacuation being

implemented a pre determined plan would be invoked and the platform attendants would encourage the passengers to leave in an orderly manner and assist PRMs from trains/platforms to the lifts. A final sweep will enable the station to be declared clear.

6.14.15. Passenger Facilities

The following facilities are to be provided at each station to enable passengers to undertake they intended journey.

- Lifts
- Escalators
- Ticketing

6.14.16. Critical Communications

Communications between operations personal will be possible using several methods;

- Secure Telephone
- Normal Telephone
- Radio
- Mobile phone
- E mail
- SMS

All these various methods will be provided so that critical communications are always possible. The communication systems within the OCC will be protected and backed-up with hot standby equipment so that partial failure is unlikely and total failure impossible.

6.14.17. Degraded Conditions

All degraded and emergency situations will need to be considered in the design process so that any affect on the infrastructure can be incorporated. In developing the full Operational Plan and Safety Case, RRTS will need to consider fully all-possible abnormal, degraded and emergency scenarios and determine the appropriate action to take.

Operation procedures and special instructions shall be developed for action to be taken in case of emergency considering following conditions

- Train on fire in tunnel – train still mobile
- Train on fire in tunnel – train stranded
- Train fire not in tunnel - train still mobile
- Train on fire not in tunnel – train stranded
- Train derailment
- Prolonged train stop
- Single line working
- Station fire
- Line side fire
- Loss of system power, signalling, telecommunications
- Loss of station power

The Rolling Stock requirement to meet the projected PHPDT for the years 2016 2031 and 2041 are given in table below.

Table 6-16: Rolling Stock requirement by year and additional cars required by year

Corridor	Length (km)	Total Requirement of cars by year				Additional cars required by year			
		2016	2021	2031	2041	2016	2021	2031	2041
Sarai Kale Khan to Modipuram and Shastri Nagar	89.5	168	186	252	279	168	18	72	21

6.15 Maintenance

To maintain the assets of the RRTS a maintenance organisation has to be set up and facilities for maintenance have to be created. An overall strategy for maintenance of assets is also to be developed. The strategy will depend to a large extent on the maintenance needs specified by the supplier of the equipment that is purchased and the contractual terms of the purchase – whether maintenance by the supplier will be a part of the contract, what will be the free warranty replacement period etc. it will also depend on the plan for outsourcing some of the maintenance work.

6.15.1. Maintenance Plan

The RRTS is going to be very intensively worked leaving very little time for maintenance. Most of the maintenance work has to be done at night when there is no train service. Keeping in mind the above factors, a broad plan for maintenance of the RRTS assets has been formulated as below.

i.) There will be a maintenance organisation set up in the RRTS which will be responsible for the repair and maintenance of all assets of the RRTS. The organisation will consist of engineers, skilled staff and managerial personnel. Some unskilled staff will also be there for manual labour intensive work.

ii.) Maintenance of different assets will be done on a preventive maintenance principle which includes directed maintenance. This means that the condition of assets will be monitored intensively through periodic inspections, on board computerised monitoring systems and from feedback of operating staff like train operators, station staff etc. This requires a high degree of computerisation on the RRRTS where asset condition data will be continuously fed into the computer and reports generated will be available to all maintenance staff. Computerised Maintenance Management Systems (MMS) are now available or can be developed for the RRTS.

iii.) Minor attention to lineside and station equipment will be done at site during night or off peak service hours. For any major repairs or scheduled maintenance, the item will be brought to the maintenance depot. For attention to fixed assets, this work will be done during non train operating hours or by taking a block.

iv.) An integrated maintenance depot will be set up at Modipuram to undertake maintenance of Rolling Stock as well as S&T, Electrical and Civil engineering equipments. A sub depot at Duhai will also be set up, mainly for stabling trains but also for carrying out petty repairs or emergency repairs.

v.) All crucial safety related maintenance work must be done in house with trained staff of the RRTS. Some non core activities like building maintenance,

electric sub station maintenance, road transport, housekeeping work etc. can be outsourced to private parties. Any

vi.) Maintenance of certain assets like the signalling system, rolling stock etc can be given to the supplier of the system, but this must be covered by strict contractual obligations and responsibilities in case of accidents.

vii.) Annual maintenance contract must be given for sophisticated sub systems like computer network, S&T equipment modules, POH of track machines and locomotives etc. The work done by the private parties must be strictly monitored by the RRTS staff.

viii.) Renewal of assets must be done after their economic life is over. The time of renewal will depend on the condition, the stated life of the asset as per the manufacturer, intensity of use etc. The Indian Railway Finance Code which lays down the codal life of Railway Assets can be a guide to determine replacement.

6.15.2. Possession Management

In order that the railway system can be properly maintained, from time to time sections of the railway will need to be taken out of use and handed over to the maintenance workers. This could range from a few minutes to several hours depending on the work involved. Each of these outages or track possessions needs to be carefully planned and coordinated so as to have minimal affect on the train operations.

Possession management is a crucial part of maintenance planning. A possession plan must be made out for the next 6 months determining the section and the duration that is required to be blocked, so that the operations staff can reschedule their trains if required after public announcement. Possession works would normally have a detailed well thought out action plan and works safety method statement. It will be centrally managed from OCC and to be executed under supervision of Station/Depot controller.

At the end of possessions it is essential that the railway is restored back to normal operating condition with no hazards to trains or persons.

6.15.3. Key Performance Indicators

To measure the effectiveness of the maintenance system and to keep track of the useful service period of assets, a range of key performance requirements and associated Key Performance Indicators (KPI's) could be used. Some suggested KPIs are given in table 6-17.:

Table 6-17: Key Performance Indicators

Measure	Target
Derailments	0 per year
Broken rails (including weld breakages)	Years 1-4: 0.006 per track km per year Years 5 onwards: 0.012 per tack km per year
OHE de-wirement	0 per year
OHE defects all systems - transformers, insulators, catenary etc.	Years 1-4: 0.006 per track km per year Years 5 onwards: 0.006xY per track km per year Y=year of operation. Capped at 10th year
Signal failures	0.9 per track km per year
Closures due to failure of	0 per year

Measure	Target
structures and earthwork	
Emergency Incident Response Time	≤ 40 minutes
Track Geometry defects	Category "A" defects Years 1-4: 0.059/TKm/Year. Cap at 0.147/TKm/Year
Planned maintenance	100% planned maintenance to be done on time. Any backlog to be wiped out within 2 months maximum.

6.15.4. Renewals

The frequency at which renewals occur will have a big impact on the time and resources necessary to maintain the assets and keep then in good working order. The period after which an asset will require renewal depends on a large number of factors like the design of the equipment, intensity of usage, obsolescence, cost of replacement etc. The RRTS will have to work out a renewal policy considering all these factors. A good guideline for renewals is the codal life of railway assets given in the Indian Railway Finance Code.

Rails will require replacement after 20 years, but this will depend on the tonnage that will be carried on the rails and whether head hardened or normal rails will be used. Machinery and Plant in depots as well as at stations will in general be requiring replacement after 10-15 years.

Other items like rolling stock and civil structures will not require replacement before the end of the project costing period of 30 years.

6.15.5. Organisation

The maintainer of the RRTS system will require a maintenance organisation similar to that shown in figure 6-14 with roles and responsibilities defined at each level.

6.15.6. Facilities

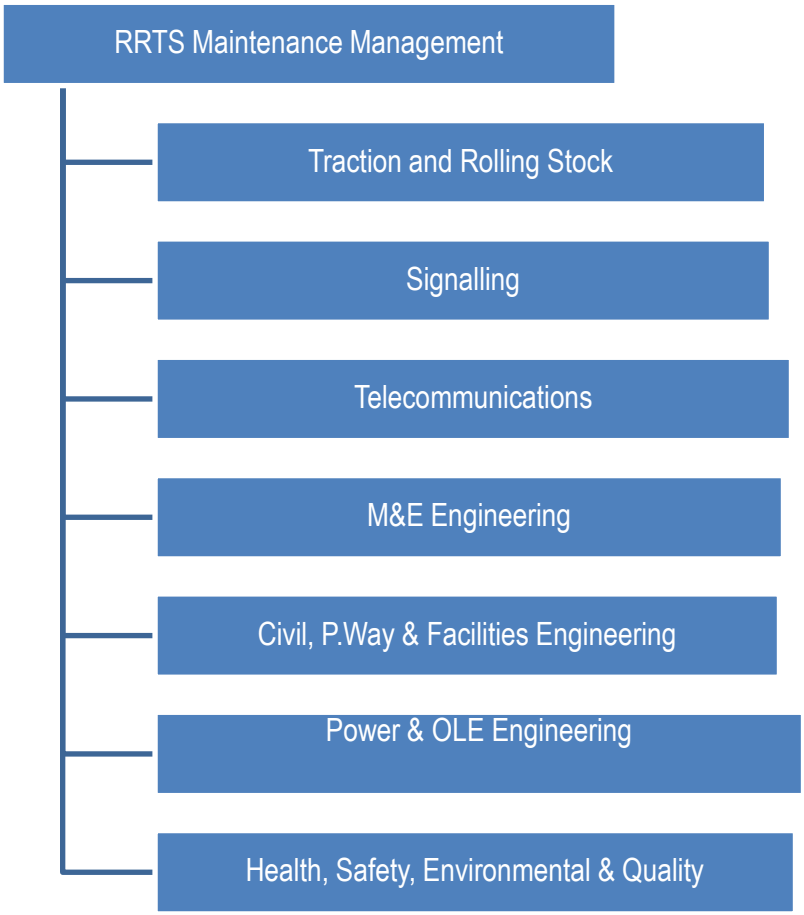
To maintain the Delhi – Meerut corridor and its stations, rail systems and trains it has been determined that the following facilities will be required;

- A maintenance depot located at Modipuram with a shed, stores and workshops for inspection, servicing and maintenance of coaches, as well as P Way, Electrical and S&T equipment
- An Operational Control Centre and Depot Control Centre
- Dry storage rooms
- Open storage areas

6.15.7. Staffing

Following the O&M requirements for efficient train operation and methodology proposed for O&M, total staff requirement for RRTS Delhi – Meerut line is estimated as 2,112.

Figure 6-14: Maintenance Organisation



6.16 Key Safety Aspects

For every successful traction system, there are certain general requirements which should be met:

The level of safety to be satisfied in the planning, design, construction, testing, commissioning and during revenue service of the RRTS with its operational and maintenance requirements shall be As Low As Reasonably Practicable (ALARP).

Consideration should be given to each of the safety factors identified below and it should be demonstrated that the ALARP principle has been effectively applied.

The objectives of safety provisions shall be that

- There should be adequate clearances for public, trains, infrastructure, and maintenance, both in normal and emergency conditions
- The railway system should be protected against unwanted intrusion and unauthorised access.
- Tunnels and other enclosed structures should provide for the safe evacuation or protection of persons under all emergency conditions.
- Elevated railway routes should provide for the safe evacuation of persons away from danger.

- Any person should be able to identify their whereabouts on the railway system using location identify markers.
- The track and its supporting structure should provide for the safe guidance and support of the train.
- The signalling system should provide for the safe routing, spacing and control of trains, even in degraded conditions.
- Station platforms and access ways shall be appropriately sized for the volume of people using them, including during degraded and emergency conditions.
- The safety of people whilst moving around the stations including allowance for luggage, wheel chairs, buggies, cycles and the like.
- A means should be provided for the monitoring and controlling the persons using the railway.
- The implementation of Fire and Life safety systems.
- The choice of materials shall be appropriate to the location and not give rise to danger in a fire situation.
- During an emergency there should be coordinated control between the railway, the emergency services and neighbouring communities.
- The interaction between road, rail, river/canal, air and sea traffic should be avoided. Where this is unavoidable then special control measures should be implemented.
- The railway should provide for the safe and secure stabling, marshalling and maintenance of the trains.
- Railway depots, marshalling yards and sidings should have safe walking routes which minimise the possible contact between trains and persons.
- Railway workers should be provided with high visibility clothing so they can be seen both during the days and at night.
- Railway workers shall be provided with a means of communication with the railway controllers.
- The means of train propulsion should be safe including during filling and energisation activities.
- The structural integrity of the trains should be maintained in normal operations and provide protection to persons on the train during an accident.
- The interiors of trains should provide a safe environment for people and their possessions.
- Trains shall have a safe means of entry and exit including during a train evacuation to trackside situation.
- The train should be provided with an effective means of communication between the driver, train attendant or central controller and the passengers
- The systems used for the guidance, control and communication interface of a train shall be compatible and not give rise to danger.
- The railway system shall have a safety management system which details the arrangements for providing safe systems of work and safe working environments.
- Each railway operator should undertake a thorough risk assessment and identify how each risk will be controlled.
- Safety targets and safety monitoring and audit will aim to continuously improve the safety systems and procedures.
- The provision of safety related training to staff, maintainers and operators with appropriate competence assessment should be implemented.
- Those persons who fulfil key safety critical roles such as signallers and track inspectors shall be regularly assessed, refreshed and provided with update training.

6.17 Depots

On the proposed corridor main depot at Modipuram and sub depot at Duhai is proposed (refer figure 6-15 and 6-16). The details are discussed below:

Modipuram Depot cum Workshop

A depot cum workshop is planned to be built at Modipuram. A total of 21 rakes will be based at Modipuram Depot cum Workshop. The depot shall be planned with the following capacities:

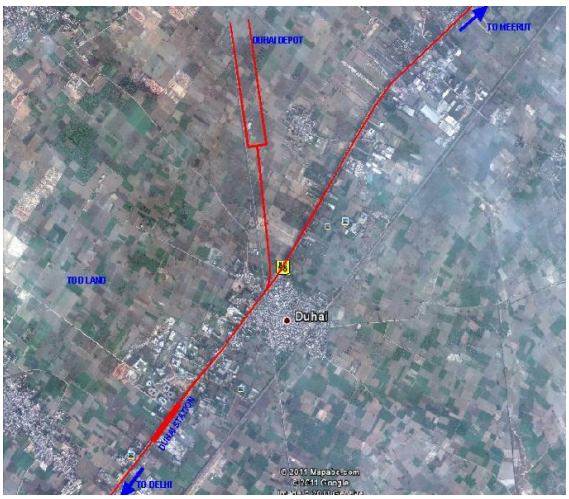
Stabling lines : 16
Inspection lines: 4
Workshop lines : 4
Heavy Repair lines: 2

Sixteen trains will be stabled on the stabling lines during off service hours. The balance 5 trains will be accommodated in the 4 Inspection lines and one train will be stabled at Modipuram station platform at night so that it can start its first service in the morning from the platform itself. If for any reason stabling at the station is not possible, then there is space available in the workshop line to accommodate the train.

Each line will be capable to accommodate 12 coach trains, even though at present only 9 coach trains are envisaged. The depot will have cleaning, inspection and repair facilities as described in the chapter on depots.

Figure 6-15: Depot at Modipuram

Figure 6-16: Depot at Duhai



6.17.1. Modipuram Depot Cum Worksop

Modipuram will be the main depot for the Meerut-Delhi RRTS corridor. All repair and maintenance work for Rolling Stock, PWay, OHE and S&T will be carried out at this depot. Therefore, the following activities are planned in the depot:

- Repair and Maintenance of Rolling Stock
- Repair and Maintenance of PWay and rail based OHE equipment like Tower Wagons, Motorized Elevated Platforms,

- Repair and Maintenance of Accident Relief Train, Diesel/Battery Locomotive, Engineering Trains
- Repair and Maintenance of all Mechanical, Electrical, S&T, P Way, ART and miscellaneous equipment, machinery and plant
- Repair and Maintenance of Depot M&P and equipment

The Modipuram depot will require accommodating 21 trains of 9 coach length in 2041. It will therefore require stabling lines, inspection lines, workshop lines and heavy repair section to accommodate these trains. The total length the train will be 288 metres. Allowing for 11 metres on either side to accommodate cross pathway, buffers, signalling requirements etc, the total length of each line will, be 310 m. To start with, in the year 2016, there will be only 6 coach trains, so the lines could be built for this with space left for future extension.

6.17.2. Facilities and activities at Depot

Various facilities planned at depot are as under (refer figure 6-17):

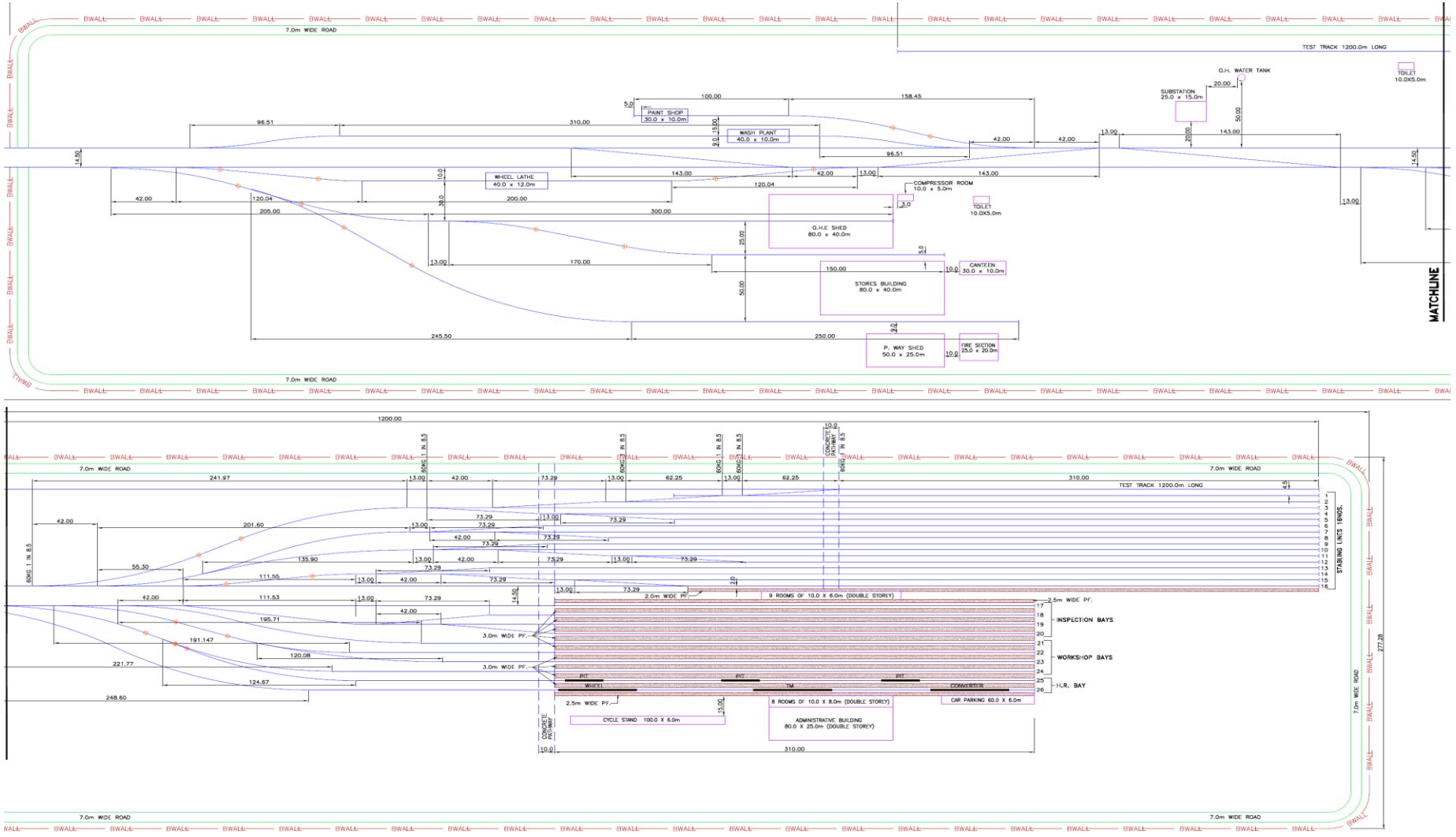
- Rolling Stock Maintenance
- Washing Line with automatic plant
- Stabling lines for the trains
- Inspection shed
- Workshop shed
- Heavy repair shed
- Underfloor wheel Lathe Shed
- Store building
- Shop floor rooms
- Coach painting
- Testing track
- Compressor room
- Administrative office
- Fire fighting and security office
- Power supplies
- Water supply, sewerage and drainage works
- Shunting locomotive
- OHE maintenance facilities
- S&T maintenance facilities
- PWay Maintenance facilities

6.17.3. Duhai Sub Depot

Since the substantial passenger traffic is between Ghaziabad and Delhi, there is need to run trains exclusively between Ghaziabad and Sarai Kale Khan as brought out in the operations study. To stable these trains during non peak and night hours, stabling lines are needed. Ideally these lines should have been at Ghaziabad, but due to space constraints, this is not possible. Therefore this provision is being made at Duhai where land is available.

The Duhai sub depot will need to accommodate stabling of 10 trains, as has been determined by the operations study. One train can be stabled at the loop line at Duhai station. The remaining 9 trains will require 9 stabling lines at Duhai depot.

Figure 6-17: Depot Layouts



Each line will be of 310 meter length, sufficient to accommodate one train. The stabling lines will be on ballasted track. There will be a walkway of 800 mm between the lines. There will be one line for stabling the Accident Relief Train.

The depot will primarily be used for stabling, cleaning and inspection of rolling stock. Some minor repair work of equipment related to P Way, S&T, OHE that can be done without taking the coach or equipment to Modipuram will also be done here.

6.18 Stations

After visiting the sites and collating available data from the developments plans, a design strategy for typical stations has been developed. All stations have been designed as 400 meters long with the usable area being 310m long. There is a buffer zone of 45m on either side. The width of every station varies depending on the peak hour passenger traffic that each station witnesses. However a minimum clear passage way of 3 meters is maintained in all platforms.

At the concourse level, all stations have ticketing facilities and entry/ exit turnstiles at each of the extremities along the length to enable division into public and restricted zones. The restricted zones comprise of station operational areas such as the Station Control Room, Station Master's Office, Staff Accommodation, Plant, Signalling and Operations Rooms, Heating Ventilation Air Conditioning (HVAC) handling units etc. The Station Service areas have been planned away from passenger movement and entry is to be restricted only to authorized personnel by either planning them behind ticketing areas or providing them in a central areas and restricting entry through security measure such a Radio Frequency Identification (RFID) cards.

The public zones are further categorized into paid and unpaid zones. The unpaid zone is where riders enter the facility, use retail services on ground level; they may use ticketing facilities or automated ticket vending machines. This zone also provides at least one manned help-desk counter in order to address passenger queries and grievances and also ensure the ticketing counters are not occupied by information seekers. The concourse is planned in such a way that maximum surveillance can be achieved by the ticket hall supervisor over ticket machines, automatic fare collection gates, stairs and escalators. Ticket machines and ticket gates are positioned to minimize cross flows of passengers and provide adequate circulation space. The paid zone begins with entry/ exit turnstiles at each of the extremities along the length. This provides access to the platform levels and other amenities.

Information Signage: Providing information and instructions to the public is another factor which should be incorporated into the design. Providing control over such as ticket gates, way-finding signs, lifts and escalators should be considered.

Multi- Modal Exchange: Appropriate measures have been taken in the design of the stations and the station precincts to allow the functioning of the multi-modality which is one of the principle features of the region. Several non-motorised forms of transportation are prevalent in these regions and modal exchange areas have to be provided.

Traffic movement and Pedestrian access: The station are designed such so as to enable the best possible location for the entries into stations from the sidewalks. A pedestrian friendly environment has been proposed through the design of stations with comfortable cross-over and multi modal interchange. Pedestrian safety is also

ensured by incorporating the guidelines. Also accessibility for the disabled has been enhanced through design considerations for barrier-free environments.

Also the vehicular traffic has been taken into consideration, thus making designs to incorporate drop off points within or adjacent the precincts.

Parking facilities: Parking facilities have been envisaged to be integrated into the station precinct wherever possible and in close walk-able vicinity for most of the other sites. Park and Ride facilities increase the effectiveness of a transit stop and also ensure great ridership.
Exit and Evacuation- All stations have been provided with a minimum of 3 main stairways, 6 escalators per platform (one in both directions), four lifts and two fire escape staircases. Each station thus shall be provided with sufficient and appropriately sized access and egress routes for passengers, staff, maintenance staff and emergency service staff, taking into consideration all their possessions (luggage, buggies, wheel chairs, etc), tools, materials and equipment.

Wash Rooms and other Public amenities- have been provided at both ends within the paid area. The number of such amenities has been calculated in accordance with Delhi Bye-Laws for Rail Stations.

Roof/ shell structure- The roof structures for all above grade stations have been designed to reflect a contemporary design language. The structures in themselves allow natural light and ventilation of the facility while creating an opportunity to harness solar energy and collect rain water.

Station Service areas- have been planned away from passenger movement and entry is to be restricted only to authorized personnel.

Possible Commercial Development: Commercial development can be designed in the station building to enable greater revenue generation opportunities.

Typologies for Station Design

The Architectural typologies of the stations along this corridor include a two below-ground/ underground station types and two types of elevated stations. In subsequent sections plans and cross sections of the two underground station and two elevated stations typologies that have been used for the various stations has been discussed.

6.18.1.1 Typology 1: Elevated Stations in the middle of the Road

These stations eliminate the need for acquiring land from various stakeholders and at the same time necessitate alternative approaches for access, drop off, parking facilities and commercial/ retail areas.

In designing for the stations on the road median adequate clearance of structural system is kept the road level. As in the case above the concourse level is connected with either sides of the road via foot over bridges where ever the site conditions permit. The stations that follow such a typology are: Mohan Nagar, Ghaziabad, Duhai and Modi Nagar. Typology 1 is shown in figure 6-18 and figure 6-19.

Figure 6-18: Typology 1 – Platform

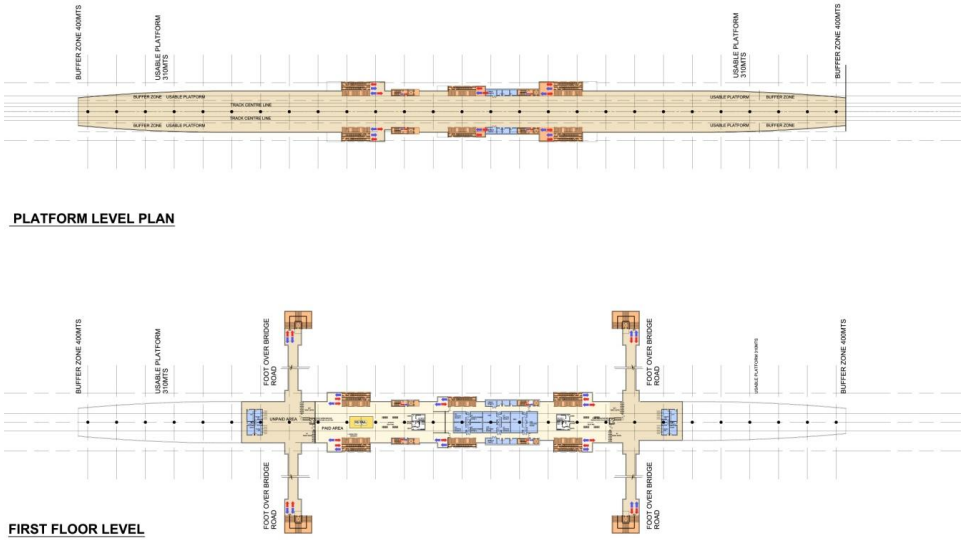
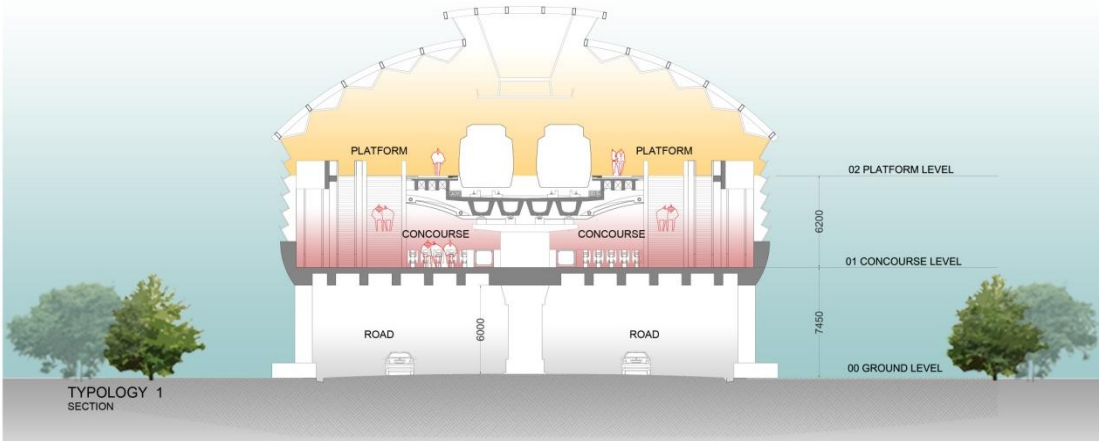


Figure 6-19: Typology 1 – Station



6.18.1.2 Typology 2: Elevated Stations on the side of the Road

These Stations typically have 3 levels- Ground, Concourse and Platform levels. The ground level has been designed to incorporate retail areas. The first benefit of incorporating a commercial aspect is that the developers can increase ridership by providing world class retail outlets and also increase the rate of return on investment via rents on the facility. Secondly if the existing shop owners in the vicinity, which are prolific in the region, be convinced to organize themselves within the station complex, land acquisition may be simplified.

The concourse level is made accessible from across the far side of the road via foot over bridges. In designing the foot over bridges, care has been taken to make universal accessibility mandatory via elevators. Stairways have been made wide enough (4.8m clear) to cater to incoming passenger loads. The stations that follow such a typology are: Sahibabad (figure 6-20 and figure 6-21).

Figure 6-20: Typology 2 – Platform

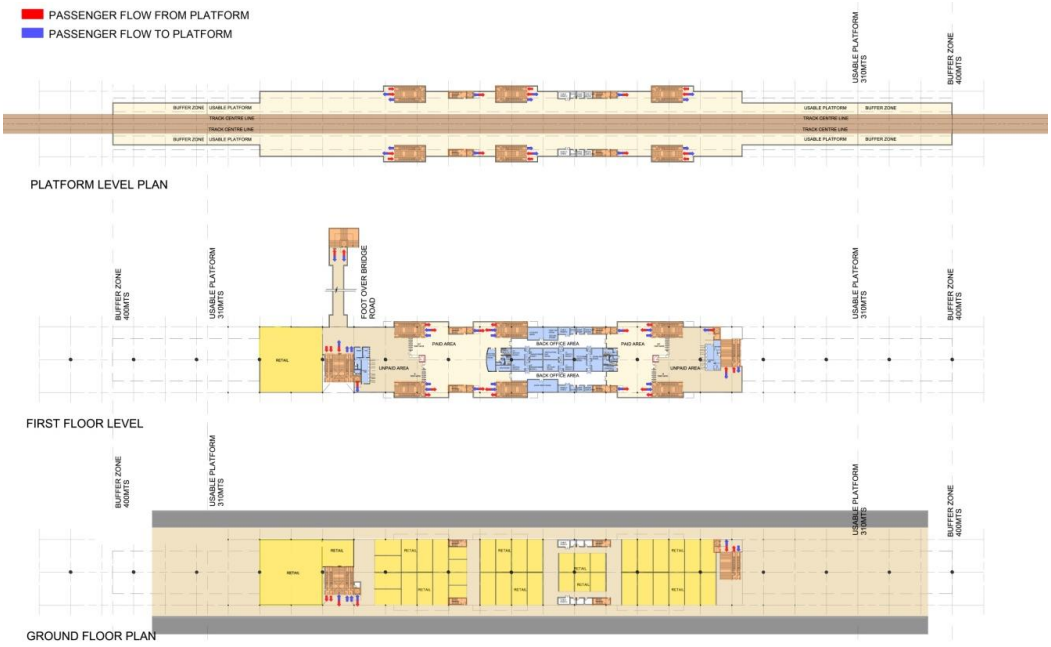
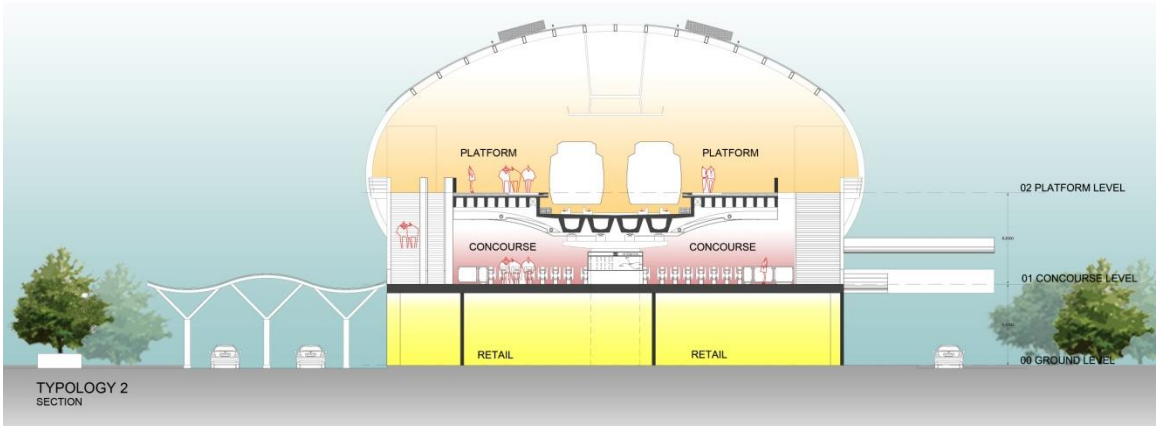


Figure 6-21: Typology 2 – Station



6.18.1.3 Typology 3:Under-ground/underground with Island Platform

In order to ensure economy in construction and material cost an 'Island' platform is recommended, wherein the platform lies in the centre and the track lines bifurcate to either sides of the platform and join together again at the other end.

The track line moves in two separate tunnels of radii 3400 mm. The rail level for these is at a minimum of 15m below ground level. Wherever these stations are under open ground or on the side of the main thoroughfare they have been designed to maximize natural light and ventilation on concourse by using skylights and ventilation shafts. The stations that follow such a typology are: Anand Vihar (figure 6-22 and 6-23).

Figure 6-22: Typology 3 – Platform

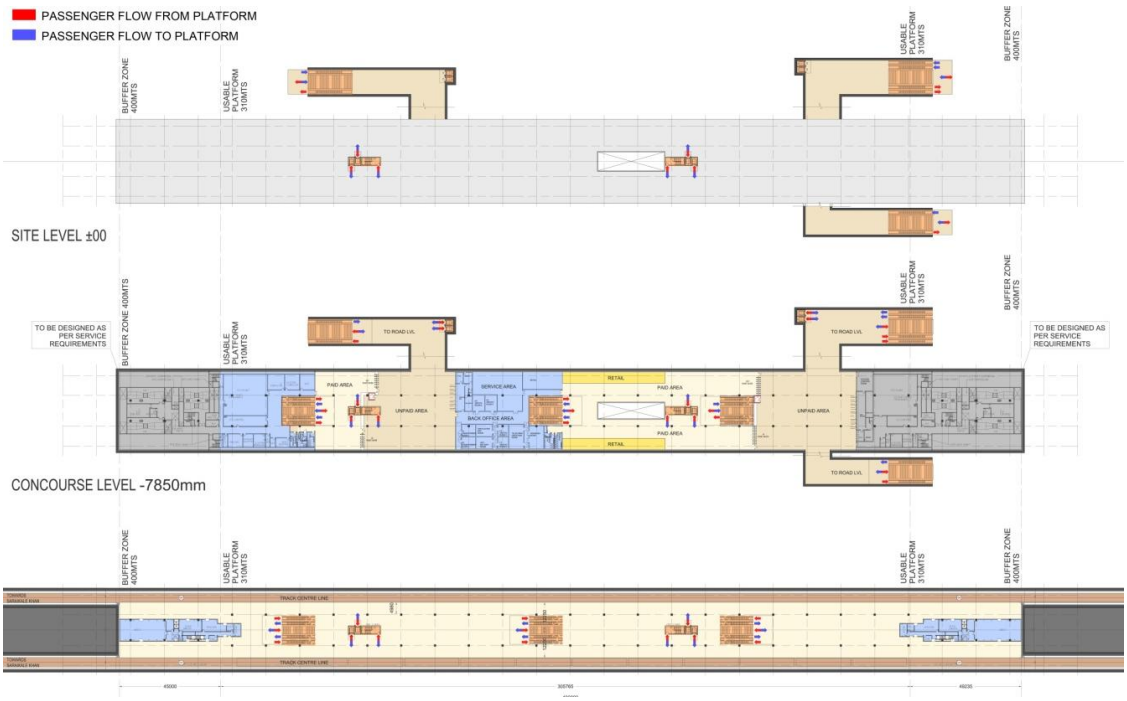
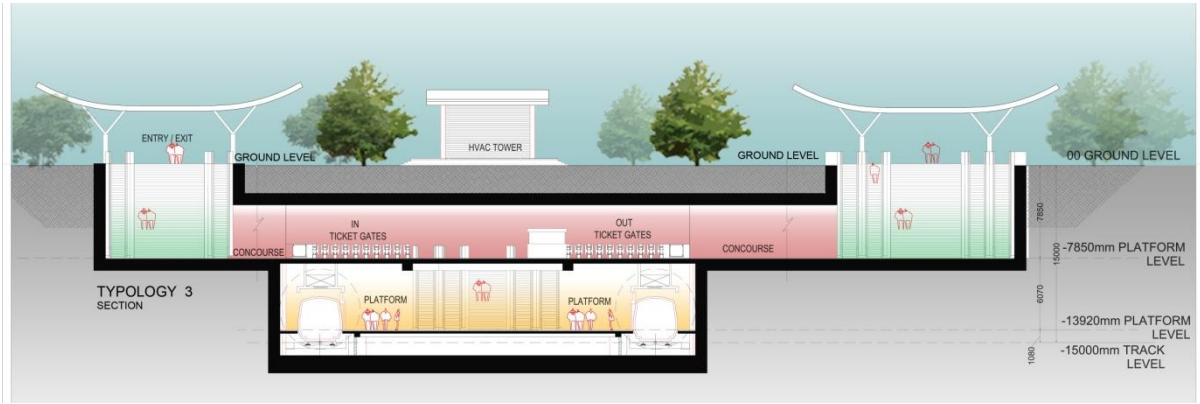


Figure 6-23: Typology 3 – Station



6.18.1.4 Typology 4: Under- ground stations with Two Islands and Four Lines

This forth typology is similar to the first typology in most respects with the exception of reduction of scale of the platform as per the passenger load.

The Shatabdi Nagar station, just before the spur begins, would consist of two islands to allow for two more lines which bifurcate from the main line to form the spur.

The stations that follow such a typology are: Meerut Central (HRS Chawk), Begum Pul, Shatabdi Nagar and Hapur Road (Nauchandi Park) (figure 6-24 and 6-25).

Figure 6-24: Typology 4 – Platform

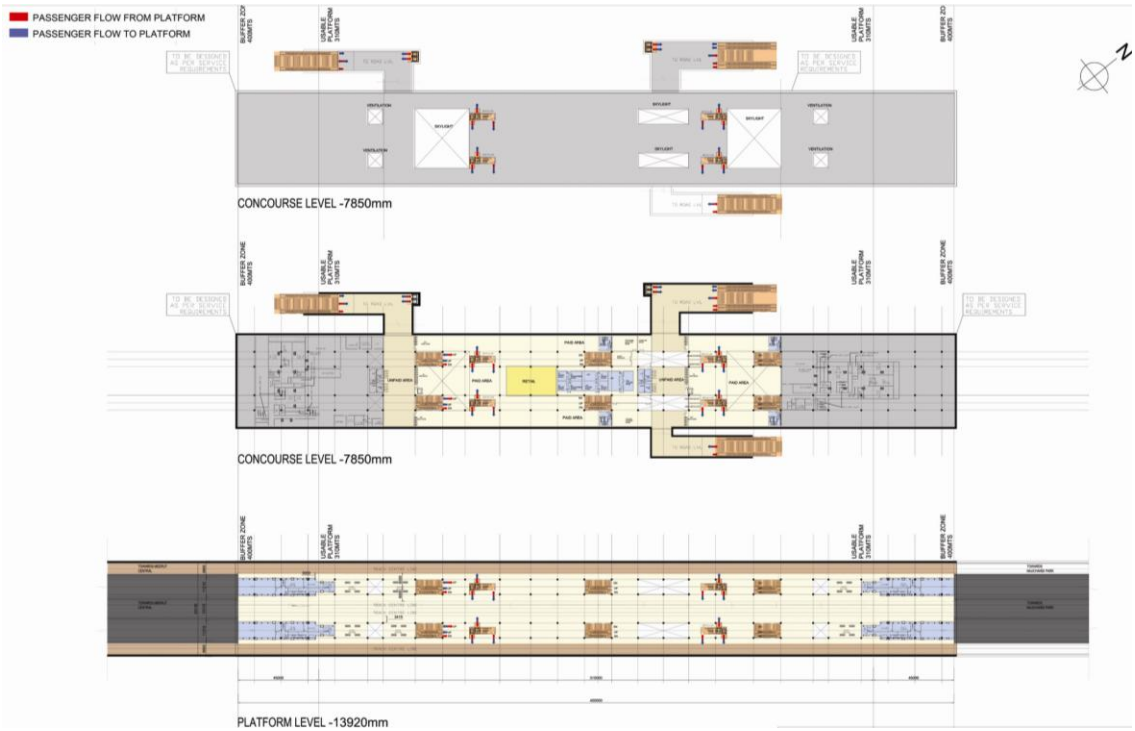


Figure 6-25: Typology 4 – Station

These typologies are governed by location on the alignment.

6.18.1.5 Description of Types of Station Design

Based on the alignment of the RRTS corridor, the space available for stations and whether or not any commercial development is planned at the station, detailed plans for individual stations has been prepared. The options for the stations have been categorised into 3 generic types, namely; fully enclosed, partially enclosed and fully open. These types represent the range of stations currently constructed around the world.

6.18.1.6 Typology for median station

For median stations, a separate station typology has been used. A typical plan and section for such station is shown in figure 6-28 and 6-29 below.

The stations which will follow this typology area Guldhar, Meerut South, Meerut North, Modipuram, Murad Nagar. Three dimensional representation of proposed Sahibabad Station is given below in figure 6-26 and 6-27.

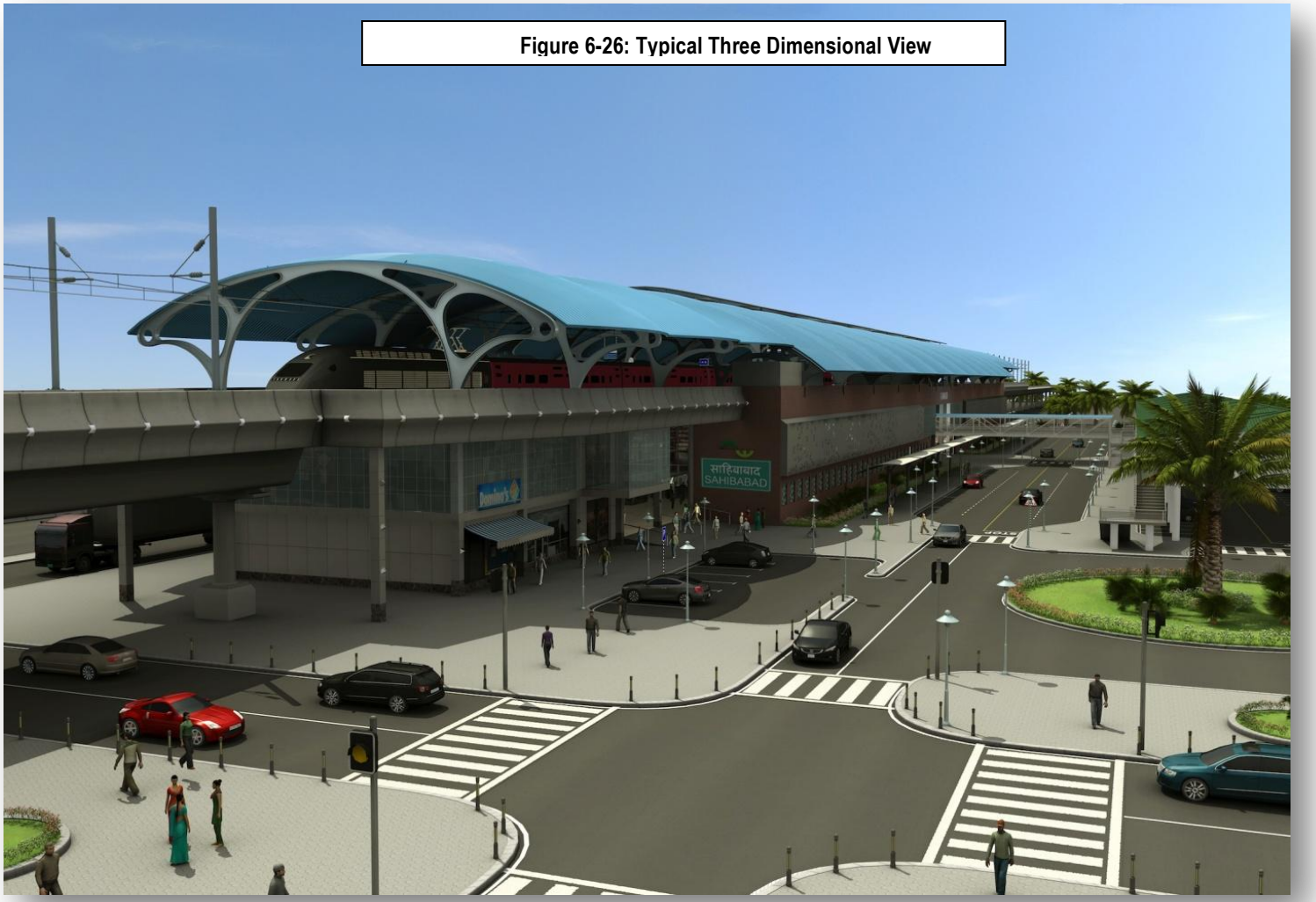
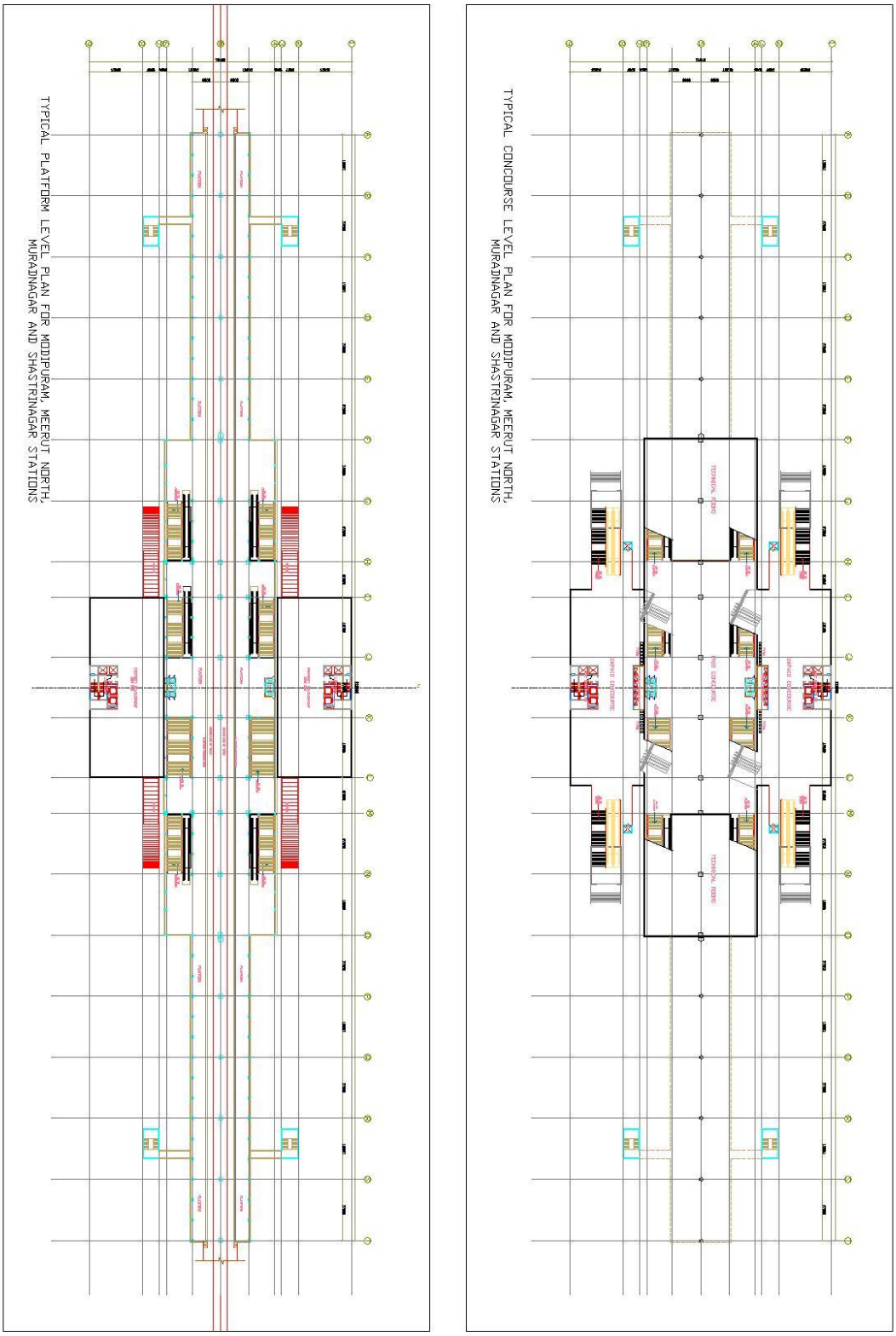


Figure 6-26: Typical Three Dimensional View

Figure 6-27: Typical Three Dimensional Station View

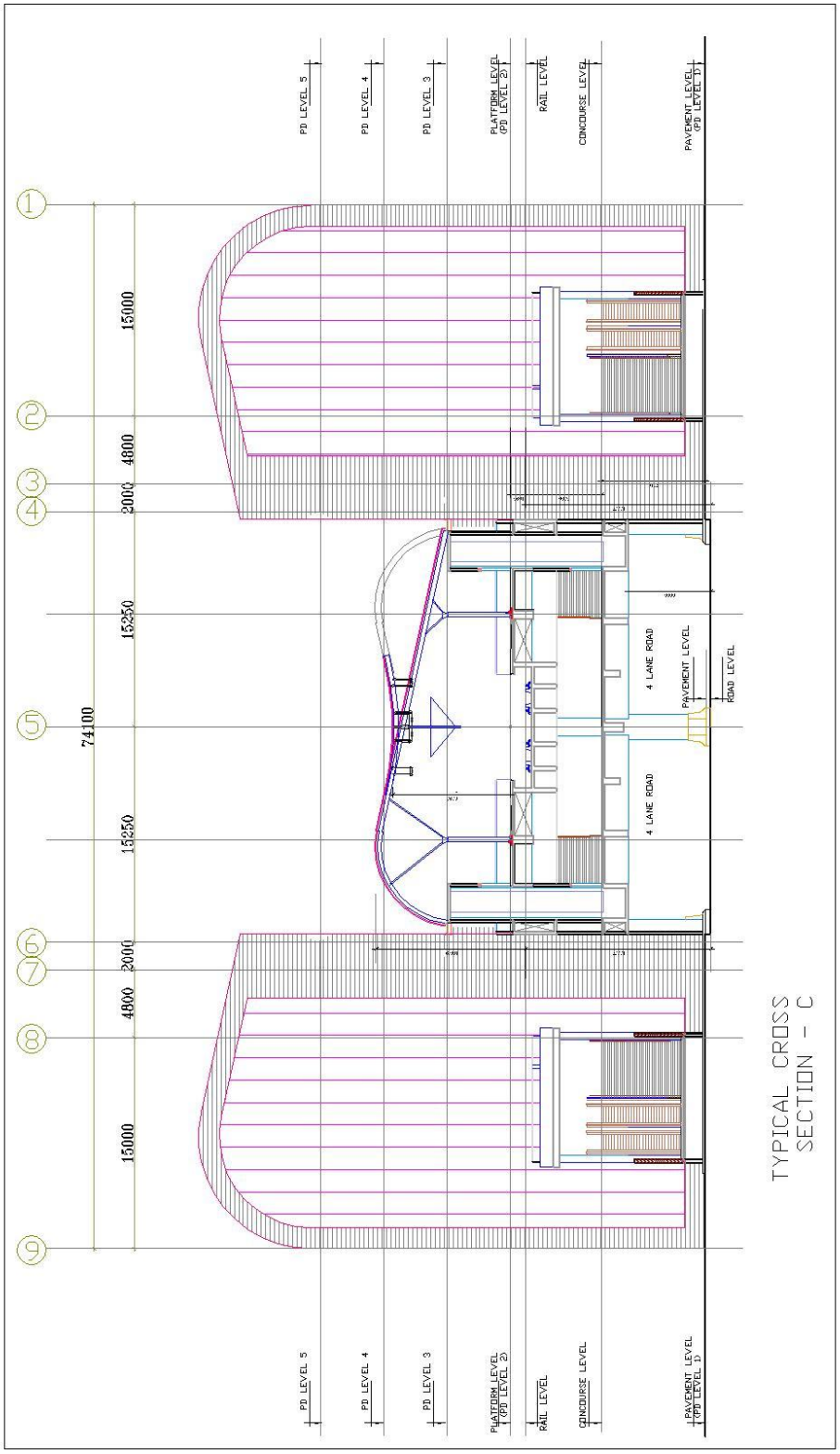
Typical Layout For Modipuram, Meerut North, Muradnagar And Shastrinagar Stations

Figure 6-28: Typical Layout of Station



Typical Cross Section Through Platform Area

Figure 6-29: Typical Cross Section of Station



Typical cross section through platform, paid & unpaid concourse and property development block.

The area statement of various stations is given in table 6-18.

Table 6-18: Station Concourse Area & Platform Area Statement

S. No	Station	Platform Area	Concourse Area
		Sqm	Sqm
1.	Nauchandi Park	4000	4000
2	Begum Pul	6400	6400
3	Meerut central (HRS Chowk)	6400	6400
4	Shatabdi Nagar	8000	12800
5	Modi Nagar	7500	10500
6	Duhai	4000	7000
7	Ghaziabad	9000	12000
8	Mohan Nagar	7500	10500
9	Sahibabad	6000	9000
10	Anand Vihar	12800	12800
11	Guldhar	8400	4050
12	Murad Nagar	7600	4025
13	Modi Puram	6150	3550
14	Meerut South	8400	4050
15	Meerut North	6150	3550
16	Shastri Nagar	6150	3550
17	Sarai Kale Khan	Integrated Station with RRTS Alwar	

6.19 Transit Oriented Development

6.19.1. Potential TOD sites

Various potential TOD sites were identified in vicinity of station areas where vacant land exists. While the small pockets identified at Mohannagar, Ghaziabad, Shatabdi Nagar and Shastrinagar are government land other large sites identified at Modipuram, Meerut south, Duhai and Gudhar belong to private property. While development of smaller sites will be developed together with stations, details of conceptual planning of typical site of large TOD is discussed in this section. The location of potential TOD areas is shown below in table 6-19 and figure 6-30 through figure 6-34.

Table 6-19: Potential TOD Areas

S. No	Location	Area Required (Hectares)	Type
1	Modipuram (Depot)	400	Mix
2	Shastri Nagar	2	Commercial
3	Shatabdi Nagar	2.4	Commercial
4	Meerut South	400	Mix
5	Duhai	400	Mix
6	Guldhar	250	Mix
7	Gaziabad	4	Commercial
8	Mohannagar	4	Commercial
Total Area		**1458.4**	

Figure 6-30: Modipuram (Depot) & Proposed TOD Area

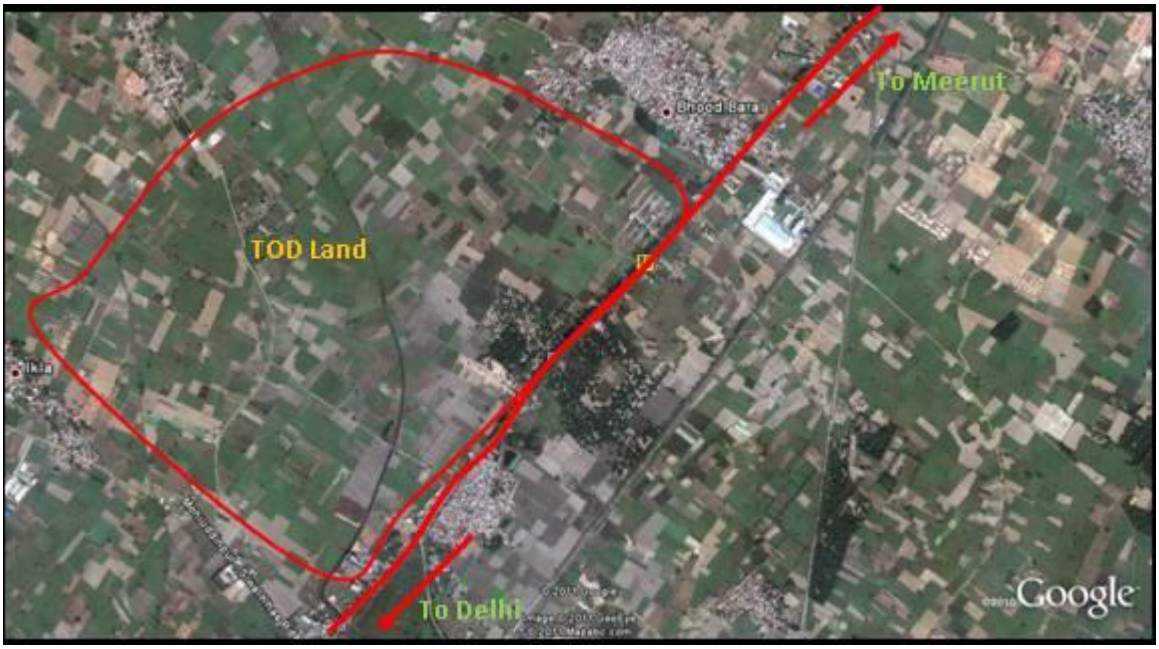


Figure 6-31: Proposed Meerut South TOD Area

Figure 6-32: Proposed Duhai TOD Area

Figure 6-33: Proposed Guldhar TOD Area

6.23.1.1 Proposed Activity Mix

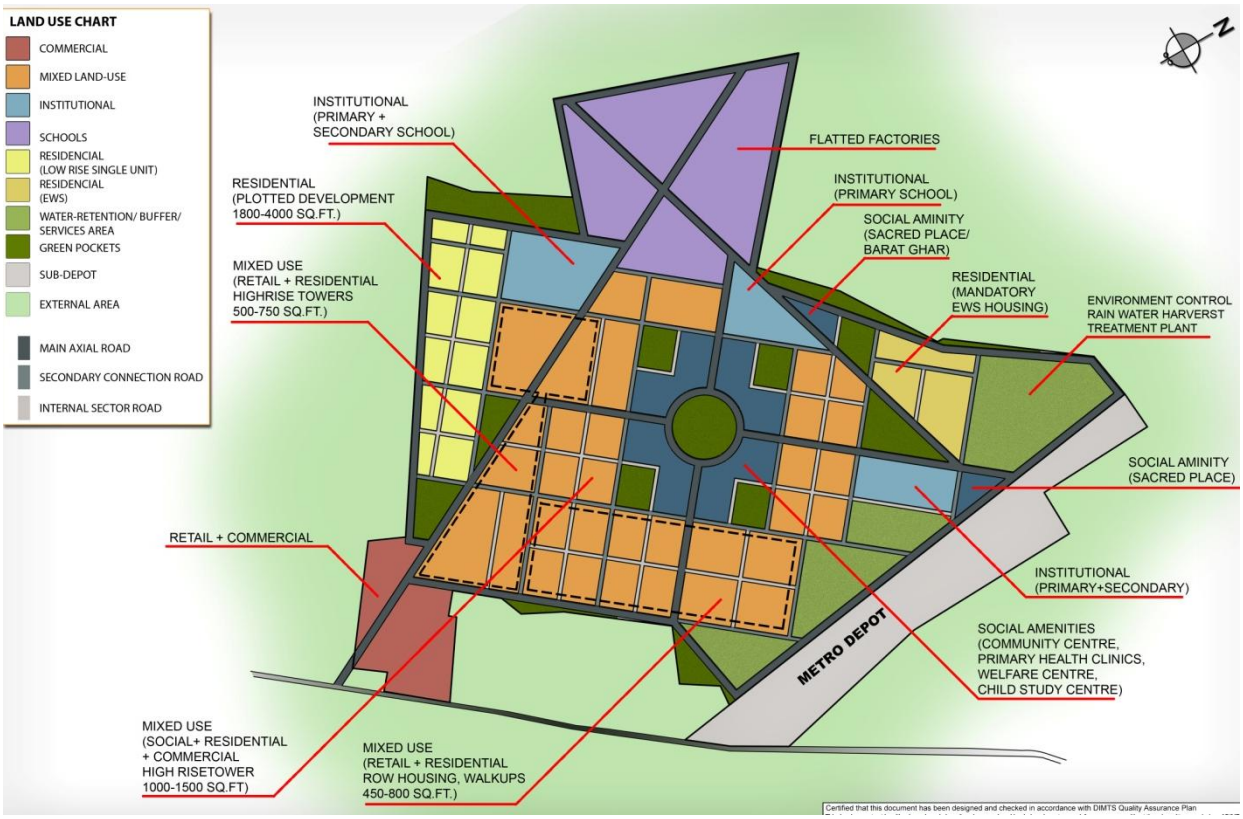
The proposed TOD will have land-uses which will promote high density near stations and encourage usage of public transport. The proposed distribution of various areas in the TOD zone will be as under in table 6-20.

Table 6-20: Activity Mix

S. No	Land -use	% Area
1	Residential	30%
2	Commercial	10%
3	Business	20%
4	Green/Transport	40%
5	Total	100%

A typical master plan of TOD (refer figure 6-34) has been created which will provide a future directions to guide the developments in TOD zones as envisaged.

Figure 6-34: Typical Master Plan of TOD Area



7. ASSUMPTIONS AND BOUNDARY CONDITIONS

7.1 Project timelines

7.1.1. Assumptions

Assumptions related to the timelines of the project considered for the assessment of the financial feasibility of RRTS project are presented in the table below:

Table 7-1 : Assumptions - Timelines

Sr. No.	Particulars	Value
1	Base year for cost estimation	2011
2	Award of contract	October 2012
3	Years of construction	4
4	Commercial operation date (COD)	1st October 2016
5	Concession period/model period	30 years
6	End of concession period/model	30th September 2046
7	No. months in a year	12
8	No. of days in a year	350

7.2 Phasing of Initial Capital Investment

It has been proposed that the Land acquisition and Rehabilitation & Resettlement (R&R) shall be completed in the first year of construction (FY 2013 & 2014). Development of depots and workshop facilities (civil works) is also proposed in the in the first year of construction for use as administrative office for the project. Activities such as Civil works, alignment and formation, overhead station buildings, underground station buildings and procurement of rolling stock shall be undertaken during first three years of construction. Establishment of power supply & substation and control systems has been proposed between third and fourth year of construction. Miscellaneous works spread out over the four year construction period. The phasing of capital investment is as given below.

Table 7-2 : Implementation Phasing Plan

Sr. No.	Particulars	Year 1	Year 2	Year 3	Year 4	Total
1	Land	100%				100%
2	Civil works, Alignment and formation	30%	30%	40%		100%
3	Overhead Station Buildings	20%	40%	40%		100%
4	Underground Station Buildings	20%	40%	40%		100%
5	Depot cum Workshop	100%				100%
6	Power Supply and Substations			85%	15%	100%
7	Control Systems			80%	20%	100%

Sr. No.	Particulars	Year 1	Year 2	Year 3	Year 4	Total
8	R&R	100%				100%
9	Miscellaneous	25%	25%	25%	25%	100%
10	Rolling Stock	33%	33%	34%		100%

7.3 Taxes and Duties

As the value of the central and state level taxes would depend on the actual amount of imports, indigenous products and services used for the project at the time of implementation, the level and rate of Custom duty, Excise duty and VAT have been assumed as per the standards followed in other similar projects in the country for example Delhi Metro project Phase III. The following table presents the rates taken for the central and state taxes:

Table 7-3 : Details of Applicable Rate of Taxes and Duties

Sr. No.	Particulars	Rate (%)
1	Custom Duty	18.6%
2	Excise duty	8.2%
3	Value Added Tax	12.5%

7.4 Financial & Taxation assumptions

Some of the key financial assumptions are given in the table below:

Table 7-4 : Key Financial Assumptions

Sr. No.	Particulars	Value
1	Inflation rate	5%
2	Discount rate	10%
3	Tax rate	32.45%
4	MAT	20.01%
5	80IA benefit taken from date	From COD
6	Tax holding in a block of 15 years	10 years
7	Interest Rate for long term borrowings (soft loan)	2%
8	Tenure – soft loan	20 years
9	Moratorium – soft loan	Nil
10	Interest Rate for future CAPEX	10%
11	Loan Tenure – future CAPEX	10 years
12	Debt : Equity Ratio – future CAPEX	80 :20

Standard taxation workings at the prevailing rates have been assumed for the financial analysis. Provision under section 80 I (A) has been considered as the project qualifies for such benefits.

7.5 Depreciation Rates

Standard depreciation workings at the prevailing rates have been assumed in the financial model. The pre-operative expenses and interest during construction are capitalized and amortized over the period of project period for depreciation purpose.

Table 7-5 : Applicable Depreciation Rates

Sr. No.	Depreciation rates	SLM for accounts (%)	WDV for taxation (%)
1	Land	0%	0%
2	Civil works & buildings	1.67%	10%
3	Rolling stock	3.17%	15%
4	Electrical works	7.07%	15%
5	Track work	1.63%	15%
6	E&M works	4.75%	15%
7	Lifts & Escalators	3.17%	15%
8	Signaling	4.75%	15%

7.6 Working Capital Assumptions

Assumption related working capital estimation is as set out below.

Table 7-6 : Working Capital Assumptions

Sr. No.	Depreciation rates	Value
1	Accounts Payable	30 Days
2	Minimum Cash Requirement	1%
3	Working Capital Margin	25%
4	Interest Cost on Bank Borrowing	10%

8. REVENUE ESTIMATION

8.1 Key Revenue Avenues

The project revenue has been estimated from following broad categories namely:

- Fare Box revenue; and
- Other Sources of Revenue
  - Revenue from Rentals (inside the Stations);
  - Revenue from Property Development;
  - Revenue from sale of Advertisement Rights; and
  - Property Transaction Cess on Transit Oriented Development area

The section below describes the details of revenue estimated from the above identified sources for the lifecycle of the project.

8.2 Fare Box Revenue

The estimation of Fare Box revenue has been estimated under different scenarios by varying the following factors:

- Fare Structure – various scenarios under fare structure have been considered including Telescopic and Non-telescopic fares, consideration of monthly pass fare, along with year on year rate of increase in the fare to account for inflation.

- Ridership –Sensitivity of fare box revenue to the overall ridership has been explored under various scenarios.

8.2.1. Comparison of Fare Structures

A Comparison has been made with fares of various modes of public transport that are currently available between Delhi Meerut section. The table below presents the 2010 fares of various modes of public transport along with approximate time taken to travel by these modes.

Table 8-1 : Mode wise Comparison of Existing Fare Structure

Sr. No.	Mode	Delhi – Meerut fare (in Rs.)	Journey Time
1	Train -AC Chair Car (Delhi - Meerut City/Meerut Cantt)	165 (71 km)	Shatabdhi :1 hr 15 min,
2	Express Train -Sleeper Class (Delhi - Meerut City/Meerut Cantt)	140 (71 km)	2 hr 10 minutes
3	State Transport bus (Non AC)	56 (67 km)	2.5 hrs
4	State Transport AC Volvo Bus	246 (67 km)	2.5 hrs

From the above mentioned table, the fares of various modes of public transport are ranging between Rs. 56 to Rs. 245 per trip and travel time varying is between 75 minutes to as high as 2.5 hours.

8.2.2. Principles of Fare Setting

The setting of fare for the proposed corridor is guided by following principles:

8.2.2.1 User's Willingness to Pay

The willingness to pay survey provides an insight into the user behaviour and their willingness to pay fare as trade-off for the time and cost savings, on the proposed corridor as compared to alternative modes. Accordingly, Stated Preference Survey was conducted along the corridor to determine willingness to pay. The acceptable fare as indicated by users was 1.07 Rs/km.

8.2.2.2 Revenue Maximising Principle

Within the bounds of user willingness to pay, the fares would be set so as to maximise the revenue generated as it has a direct bearing on financial viability of the project.

For determining fare sensitivity and its impact on total revenue collection, revenue maximisation curve was developed. Ridership was arrived at 50 %, 75 %, 100 %, 125%, 150 % of fares. Fare elasticity with respect to ridership is presented in the table below.

Table 8-2 : Fare Elasticity with Respect to Ridership

Sr. No.	Percentage Variation in Fare	Elasticity of Ridership
1	50%	6.09%
2	75%	3.08%
3	100%	0.00%
4	125%	-3.11%
5	150%	-6.21%
6	175%	-9.26%
7	200%	-12.21%

It may be observed that revenue units increase with higher fares and do not indicate declining trend even at very large fare values. Since there is no revenue increase observed in reducing fare levels, values of acceptable fare levels obtained from stated preference/WTP surveys are recommended. .

Table 8-3 : Tentative Distance between Stations

Sr. No	Stations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Shastri Nagar	0	4	31	27	19	16	9	15	22	33	40	44	48	50	53	59	68
2	Hapur Road	4	0	28	24	15	13	5	12	19	29	36	40	44	46	49	55	65
3	Modi Puram	31	28	0	4	12	15	23	29	36	47	54	58	62	64	67	73	83
4	Meerut North (Pallavpuram)	27	24	4	0	8	11	19	26	33	43	50	54	58	60	63	69	79
5	Begum Pul	19	15	12	8	0	3	10	17	24	34	42	45	49	52	55	60	70
6	Meerut Central	16	13	15	11	3	0	8	15	22	32	39	43	47	49	52	58	68
7	Shatabdi Nagar	9	5	23	19	10	8	0	7	14	24	31	35	39	41	44	50	60
8	Meerut South	15	12	29	26	17	15	7	0	7	17	24	28	32	35	38	43	53
9	Modinagar	22	19	36	33	24	22	14	7	0	10	17	21	25	28	31	36	46
10	Muradnagar	33	29	47	43	34	32	24	17	10	0	7	11	15	17	20	26	36
11	Duhai	40	36	54	50	42	39	31	24	17	7	0	4	8	10	13	19	29
12	Guldhar	44	40	58	54	45	43	35	28	21	11	4	0	4	6	9	15	25
13	Ghaziabad	48	44	62	58	49	47	39	32	25	15	8	4	0	2	5	11	21
14	Mohan Nagar	50	46	64	60	52	49	41	35	28	17	10	6	2	0	3	9	19
15	Sahibabad	53	49	67	63	55	52	44	38	31	20	13	9	5	3	0	6	16
16	Anand Vihar	59	55	73	69	60	58	50	43	36	26	19	15	11	9	6	0	10
17	Saraikale khan	68	65	83	79	70	68	60	53	46	36	29	25	21	19	16	10	0

Table 8-4 : Proposed Station wise Telescopic Fare Structure – Full Fare

Sr. No	Stations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Shastri Nagar	0	23	34	30	23	23	23	23	24	35	43	47	51	54	57	63	74
2	Hapur Road	23	0	30	26	23	23	23	23	23	31	39	43	48	50	53	59	70
3	Modi Puram	40	30	0	23	23	23	25	32	39	50	58	62	66	69	72	78	89
4	Meerut North	30	26	23	0	23	23	23	28	35	46	54	58	62	65	68	74	85
5	Begum Pul	30	23	23	23	0	23	23	23	26	37	45	49	53	56	59	65	76
6	Meerut Central	23	23	23	23	23	0	23	23	24	35	42	46	51	53	56	62	73
7	Shatabdi Nagar	23	23	25	23	23	23	0	23	23	26	34	38	42	45	48	54	65
8	Meerut South	23	23	32	28	23	23	23	0	23	23	27	31	35	37	41	47	57
9	Modinagar	30	23	39	35	26	24	23	23	0	23	23	23	27	30	33	39	50
10	Muradnagar	40	31	50	46	37	35	26	23	23	0	23	23	23	23	23	28	39
11	Duhai	50	39	58	54	45	42	34	27	23	23	0	23	23	23	23	23	31
12	Guldhar	50	43	62	58	49	46	38	31	23	23	23	0	23	23	23	23	27
13	Ghaziabad	60	48	66	62	53	51	42	35	27	23	23	23	0	23	23	23	23
14	Mohan Nagar	60	50	69	65	56	53	45	37	30	23	23	23	23	0	23	23	23
15	Sahibabad	60	53	72	68	59	56	48	41	33	23	23	23	23	23	0	23	23
16	Anand Vihar	70	59	78	74	65	62	54	47	39	28	23	23	23	23	23	0	23
17	Saraikale khan	80	70	89	85	76	73	65	57	50	39	31	27	23	23	23	23	0

Table 8-5 : Proposed Station wise Telescopic Fare Structure – Discounted Fare Structure (Monthly Pass)

Sr. No	Stations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Shastri Nagar	0	17	26	23	17	17	17	17	18	26	32	35	38	41	43	47	56
2	Hapur Road	17	0	23	20	17	17	17	17	17	23	29	32	36	38	40	44	53
3	Modi Puram	30	23	0	17	17	17	19	24	29	38	44	47	50	52	54	59	67
4	Meerut North	23	20	17	0	17	17	17	21	26	35	41	44	47	49	51	56	64
5	Begum Pul	23	17	17	17	0	17	17	17	20	28	34	37	40	42	44	49	57
6	Meerut Central	17	17	17	17	17	0	17	17	18	26	32	35	38	40	42	47	55
7	Shatabdi Nagar	17	17	19	17	17	17	0	17	17	20	26	29	32	34	36	41	49
8	Meerut South	17	17	24	21	17	17	17	0	17	17	20	23	26	28	31	35	43
9	Modinagar	23	17	29	26	20	18	17	17	0	17	17	17	20	23	25	29	38
10	Muradnagar	30	23	38	35	28	26	20	17	17	0	17	17	17	17	17	21	29
11	Duhai	38	29	44	41	34	32	26	20	17	17	0	17	17	17	17	17	23
12	Guldhar	38	32	47	44	37	35	29	23	17	17	17	0	17	17	17	17	20
13	Ghaziabad	45	36	50	47	40	38	32	26	20	17	17	17	0	17	17	17	17
14	Mohan Nagar	45	38	52	49	42	40	34	28	23	17	17	17	17	0	17	17	17
15	Sahibabad	45	40	54	51	44	42	36	31	25	17	17	17	17	17	0	17	17
16	Anand Vihar	53	44	59	56	49	47	41	35	29	21	17	17	17	17	17	0	17
17	Saraikale khan	60	53	67	64	57	55	49	43	38	29	23	20	17	17	17	17	0

8.2.3. Recommended Fare Structure

An appropriate fare structure has been proposed considering the following factors:

i.) Passengers' willingness to shift from their current mode of transport to proposed RRTS.

a) As indicated in the travel demand forecast study, the passenger willingness to shift has been conducted
b) The outcome of the travel demand forecast survey has suggested that the commuters travelling by personal vehicle (primarily cars and taxis) have shown highest willingness to shift making them one of the prime target customers of RRTS.
c) Also daily commuters travelling by state transport (Non AC) buses would also be willing to shift considering the saving in journey time achieved by shifting from bus to RRTS.

ii.) Considering the above factors a fare of Rs 90 (at January 2011 levels) is proposed between Sarai Kale Khan station and Modi Puram station. The fare for subsequent years has been proposed to be increased at a nominal rate 5% per annum for the entire period of the project.

8.2.3.1 Fare for Intermediate Stops

It has been observed that in other similar projects like Delhi Metro or AC fare of Indian Railways, Telescopic fare structure has been adopted. A similar structure is proposed for Delhi Meerut RRTS. It has been assumed that the minimum fare for a single journey would be kept at 25% (~Rs. 23) of full fare between Sarai Kale Khan and Modi Puram station. Beyond this the fare would be prorated based on distance between the boarding and alighting stations.

The tables below provides the distance matrix and the proposed fare structure between stations (full fare) and Concessional fare for monthly pass holders at a (25% of full fare) discounted fare.

8.3 Ridership Estimation

The ridership of RRTS Delhi Meerut corridor has been estimated in detail under various scenarios of speed, waiting time and fare structure. However, following table presents estimated ridership based on TOD scenario with full fare and concessional fare. It is assumed that 75% of the total commutes would pay full fare and 25% of the total commuters would take monthly pass at a concessional fare. Further, due to reduction in total fare for about 25% of the full fare could result in increase in ridership by 3.08% in monthly pass category.

Table 8-6 : Estimated Ridership

Sr. No.	Daily Ridership numbers	2016	2021	2031	2041
		In Lakhs			
1	Total Estimated Ridership	5.71	7.50	9.07	11.30
2	Ridership -Full Fare Structure	4.29	5.62	6.80	8.48
3	Ridership – Concessional Fare	1.47	1.93	2.34	2.91

The daily ridership for years in between 2016, 2021, 2031, 2041 and for the years beyond 2041 has been calculated by interpolation/ extrapolations of these ridership forecast.

8.4 Fare Box Revenue

The following key assumptions have been used to arrive at the yearly revenues for the project:

- Two separate fares (no concession full fare and concessional monthly pass fare) have been used for revenue estimation.
- In addition to above a ramp rate of 80% and 90% has been taken in the first two years of operations to account for any possibility of low ridership during the initial years of the operations.
- An escalation of 5% per annum has been assumed in the fare structure for the entire concession period

Based on the fare and ridership estimate as discussed in the articles above, the table below summarizes the yearly revenue estimate from FY 2016-2017 (considering 6 months operations in FY17) till 20045-46.

Table 8-7 : Estimated Yearly Fare Box Revenue

Sr. No.	Year	Yearly Fare Box Revenue (Rs. Millions)
1	2017	3,511
2	2018	8,476
3	2019	10,452
4	2020	11,599
5	2021	12,873
6	2022	14,286
7	2023	15,297
8	2024	16,380
9	2025	17,539
10	2026	18,780
11	2027	20,109
12	2028	21,532
13	2029	23,055
14	2030	24,687
15	2031	26,434
16	2032	28,304
17	2033	30,337
18	2034	32,515
19	2035	34,850
20	2036	37,352
21	2037	40,034
22	2038	42,909
23	2039	45,989
24	2040	49,292
25	2041	52,831
26	2042	56,624
27	2043	60,690

Sr. No.	Year	Yearly Fare Box Revenue (Rs. Millions)
28	2044	65,048
29	2045	69,718
30	2046	74,724

Following table presents break-up of estimated Revenue from fare box from full fare revenue and concessional fare revenue from monthly pass holders.

Table 8-8 : Distribution of Fare Box Revenue

Sr. No.	Description	2018	2021	2031	2041
		Rs. Million / Year			
	Fare Box				
1	Full Fare	6,736	10,230	21,008	41,986
2	Concessional Fare	1,740	2,642	5,426	10,845
3	Total Fare Box Revenue	8,476	12,872	26,434	52,831

8.5 Other Revenue Sources

Besides farebox revenue, other potential sources of revenue have been identified. The identified sources are

a) Commercial Areas in station building complex
b) Commercial areas adjacent secondary buildings
c) Advertisement Panels
d) TOD zones

8.5.1. Commercial Area Developed at Stations

For development of commercial area at each stations due care has been given to the factors such as

- location of station– commercial potential
- type of stations – elevated and underground
- area at concourse level and additional area available within the station building
- Current rental values in the city and rent escalation potential

Suitable values for occupancy rate and increase in rental values per annum (assumed at 5%) etc., have been taken to have a realistic estimate of the revenue potential of the commercial areas at the stations. It has been assumed that the occupancy would increase at a rate of 30% to 75% per annum after Commercial Operation Date (COD) of the project depends on the station location.

The table below gives the details of areas to be developed at each station for commercial exploitation along with assumed rental value and other parameters.

Table 8-9 : Station wise Commercial Area Proposed & Revenue Assumption

Sr. No.	Stations	Commercial area (Sqm)	Rental value (Rs/ sqm) Jan 2011	Starting occupancy (%)	Increase in occupancy per annum
1	Shastri Nagar	532.50	100	50%	30%
2	Hapur Road	600.0	100	50%	30%
3	Modi Puram	532.50	100	50%	30%
4	Meerut North	532.50	100	50%	30%
5	Begum Pul	960.00	150	60%	50%
6	Meerut Central	960.00	150	60%	50%
7	Shatabdi Nagar	1,920.00	100	50%	40%
8	Meerut South	607.50	100	50%	30%
9	Modinagar	1,575.00	100	50%	30%
10	Muradnagar	603.75	100	40%	30%
11	Duhai	1,050.00	100	40%	30%
12	Guldhar	607.50	100	40%	30%
13	Ghaziabad	1,800.00	150	60%	40%
14	Mohan Nagar	1575.00	150	60%	40%
15	Sahibabad	1,350.00	150	60%	40%
16	Anand Vihar	1,500.00	250	75%	50%
17	Saraikale khan	1,500.00	250	75%	50%

Based on the aforesaid assumption the total revenue estimated from commercial /kiosks at station building is at Rs. 44.69 Million for the year 2018.

Table 8-10 : Station wise Revenue from Commercial Area Proposed

Sr. No.	Stations	2018	2021	2031	2041
		Rs. Million /Year			
1	Shastri Nagar	0.56	0.99	1.61	2.63
2	Hapur Road	0.63	1.12	1.82	2.96
3	Modi Puram	0.56	0.99	1.61	2.63
4	Meerut North	0.56	0.99	1.61	2.63
5	Begum Pul	2.08	2.68	4.37	7.11
6	Meerut Central	1.39	1.79	2.91	4.74
7	Shatabdi Nagar	2.16	3.57	5.82	9.48
8	Meerut South	0.64	1.13	1.84	3.00
9	Modinagar	1.65	2.93	4.78	7.78
10	Muradnagar	0.50	1.12	1.83	2.98
11	Duhai	0.88	1.95	3.18	5.19
12	Guldhar	0.51	1.13	1.84	3.00
13	Ghaziabad	2.86	3.94	6.41	10.45
14	Mohan Nagar	2.50	3.45	5.61	9.14
15	Sahibabad	16.43	22.64	36.89	60.08
16	Anand Vihar	6.05	7.00	11.40	18.58
17	Saraikale khan	4.73	5.47	8.91	14.51
	Total	**44.69**	**62.91**	**102.47**	**166.91**

8.5.2. Commercial Area Developed in adjacent Secondary Buildings

The revenue from property development is another important source of revenue for the project and hence it has been proposed that commercial complexes to be developed adjacent to the station buildings where such pockets of land is available with the State Government/its departments. Following sites have been identified for purpose of developing commercial/office complexes.

Table 8-11 : Station wise Property Development Proposed

Sr. No.	Location	Permissible Built-up Area @4 FAR	Proposed Built-up Area
		Sq.m	Sq.m
1	Shastri Nagar	82,000	82,000
2	Modi Puram	4,000	4,000
3	Meerut North	2,000	2,000
4	Begum Pul	24,000	24,000
5	Shatabdi Nagar	9,6000	9,600
6	Meerut South	8,000	8,000
7	Muradnagar	8,000	8,000
8	Guldhar	7,800	7,800
9	Ghaziabad	160,000	160,000
10	Mohan Nagar	160,000	160,000
11	Sahibabad	110,000	110,000

Following factors have been considered while estimating the built-up area for commercial purpose at the identified sites.

- Extent of land availability and its proximity to the proposed stations
- State/ city development norms - an FAR of 400% has been taken as allowed for Delhi Metro projects to exploit the full revenue potential of the area as well as rapid development of the area due to the Project
- State/ district development plans
- Current rental values in the city and rent escalation potential

Appropriate occupancy rate and increase in rental values per annum (assumed at 5%) etc., have been considered. It has been assumed that the occupancy would increase at a rate of 30% to 75% per annum after Commercial Operation Date (COD) of the project depends on the property location.

Year wise estimated revenue from rentals adjacent secondary buildings is set out below.

Table 8-12 : Station wise Revenue from Adjacent Secondary Building Complexes

Sr. No.	Stations/Property location	2018	2021	2031	2041
		Rs. Million /Year			
1	Shastri Nagar	67.16	119.61	194.83	317.35
2	Modi Puram	0.56	0.99	1.61	2.63
3	Meerut North	1.64	2.92	4.75	7.74
4	Begum Pul	40.82	52.51	85.53	139.32
5	Shatabdi Nagar	84.67	140.03	228.09	371.53

Sr. No.	Stations/Property location	2018	2021	2031	2041
		Rs. Million /Year			
6	Meerut South	6.55	11.67	19.01	30.96
7	Muradnagar	5.24	11.67	19.01	30.96
8	Guldhar	5.11	11.38	18.53	30.19
9	Ghaziabad	254.02	350.07	570.22	928.83
10	Mohan Nagar	254.02	350.07	570.22	928.83
11	Sahibabad	174.64	240.67	392.03	638.57
	Total	**894.43**	**1291.59**	**2103.83**	**3426.91**

8.5.3. Advertisement Panels

The potential sources for revenue from advertisement on RRTS Delhi –Ghaziabad – Meerut corridor shall be as follows:

- Advertisement panels inside the 17 proposed station locations
- Advertisement panels inside and outside the train
- Advertisement on viaduct at potential places wherever possible.
- Digital displays inside the stations and trains.

As most of the Delhi Ghaziabad- Meerut line passes through virgin areas the advertisement revenue potential does not have a benchmark for estimation. Considering this we have taken a conservative view on the revenue estimates from advertisement. The revenue from advertisement has been kept at 1% of the farebox revenue for each respective year.

Year wise estimated advertisement revenue is as given in the table below.

Table 8-13 : Estimated Revenue from Commercial Areas and Advertisement Panels

Sr. No.	Year	Commercial area inside stations	Commercial - secondary buildings	Advertisement Panels	Total
		Rs. Million / Year			
1	FY 2017*	31	611	35	677
2	FY 2018	45	894	85	1,024
3	2019	55	1,143	105	1,302
4	2020	59	1,227	116	1,403
5	2021	63	1,292	129	1,483
6	2022	66	1,356	143	1,565
7	2023	69	1,424	153	1,646
8	2024	73	1,495	164	1,732
9	2025	76	1,570	175	1,822
10	2026	80	1,648	188	1,916
11	2027	84	1,731	201	2,016
12	2028	89	1,817	215	2,121
13	2029	93	1,908	231	2,232
14	2030	98	2,004	247	2,348
15	2031	102	2,104	264	2,471
16	2032	108	2,209	283	2,600
17	2033	113	2,319	303	2,736

Sr. No.	Year	Commercial area inside stations	Commercial - secondary buildings	Advertisement Panels	Total
		Rs. Million / Year			
18	2034	119	2,435	325	2,879
19	2035	125	2,557	348	3,030
20	2036	131	2,685	374	3,189
21	2037	137	2,819	400	3,357
22	2038	144	2,960	429	3,534
23	2039	151	3,108	460	3,720
24	2040	159	3,264	493	3,916
25	2041	167	3,427	528	4,122
26	2042	175	3,598	566	4,340
27	2043	184	3,778	607	4,569
28	2044	193	3,967	650	4,811
29	2045	203	4,165	697	5,065
30	2046	213	4,374	747	5,334

8.5.4. *Transit Oriented Development Zones*

A transit-oriented development (TOD) is a mixed-use residential or commercial area designed to maximize access to public transport, and often incorporates features to encourage transit ridership. A TOD neighborhood typically has a center with a transit station or stop (train station, metro station, or bus stop), surrounded by relatively high-density development with progressively lower-density development spreading outwards from the center.

8.5.5. *Transaction Cess on TOD*

Transit Oriented Development (TOD) is being explored along the RRTS corridor from Delhi to Meerut. The entire RRTS corridor will have four TOD zones at Modipuram, Meerut South, Duhai and Guldhar with the total area ranging between 250 hectares to 400 hectares. The TOD shall have a high (FAR), high density and mixed land use. Further, land use densification would be required to be done along the influence area of the corridor and at all selected RRTS stations. The table below summarizes the TOD area and provides the details of the TOD zones and area considered for further analysis in the business plan report.

Table 8-14 : Details of TOD Zones

Sr. No.	TOD Zones	Area	Proposed Land use
		Ha.	
1	Modipuram	346	Mixed
2	Meerut South	400	Mixed
3	Duhai	400	Mixed
4	Guldhar	250	Mixed
	Total	**1396**	

According to Urban Development Plans Formulation and Implementation (UDPFI) guidelines used for city development strategies, the density in a city can range between 150 to 350 persons per hectare (pph). Hence it is assumed that the TOD

zone will be a medium population density area with a density of 225 pph. Out of the total 1,396 hectares land area, 60% of the area proposed for development in terms of the table given below.

We have taken a conservative view on the potential TOD area and have only taken 1,396 hectares for revenue calculations in the business plan out of about 2,000 hectares available. This gives enough room for against adjustment or any downside in revenues arising out of TOD.

Table 8-15 : Proposed Built-up area

Sr. No.	Description	%	Developed Area	FAR	Built-up Area
1	Total Area	1396 ha			
2	Developed Area	60%			
a	Residential	30%	419 Ha	3	1256 Ha
b	Commercial	10%	140 Ha	3	419 Ha
c	Office	20%	279 Ha	4	1,117 ha
d	Green Area / Roads/Common area /others	40%	558 Ha	-	-

Due to the RRTS project the value of land and value of the built-up area would increase in these proposed TOD zones and adjacent influence areas. Further velocity of transaction of property would be very high due to the speculation in these zones. To raise funds required for development of the project, it is proposed that the state government could levy cess on each property transaction both on land and built up area in the aforesaid TOD zones. Following rates have been used in this Feasibility Report that could be charged at the time of registration of property from the buyers/sellers.

Table 8-16 : Proposed Cess Rate

Sr. No.	Description	Unit	Rate
			Rupees
1	Land /Site/Plot	Per sq.m / transaction	1,000
2	Developed Area		
a	Residential	Per sq.m/ transaction	1,000
b	Commercial	Per sq.m/ transaction	2,000
c	Office	Per sq.m/ transaction	1,500

It is assumed that towards completion of construction of RRTS project, the velocity of transaction would increase from 5% to 20%. To estimate the total Cess generated from TOD area following formula adopted;

Total Cess for the year = Rs. 1,000 per sqm per transaction X Total TOD area X velocity of transaction for the corresponding year.

The Cess could be applied within 3 months of the release of this Report to capture the initial burst of Capital inflow into the TOD zone. This amount during construction of the project could be utilized towards state government's equity contribution for the

project. Further it is assumed that the state government would come out with development plan for TOD area within next six months itself. Following table provides year wise estimated Cess during the construction period. The total estimated Cess during construction is Rs.7,678 Million.

Table 8-17 : Estimated Transaction Cess during Construction

Sr. No.	Year	Velocity of Transaction	Area	Total Cess
		%		Rs. Million
1	2012	5%	1396 ha	698
2	2013	10%	1396 ha	1,396
3	2014	10%	1396 ha	2,792
4	2015	20%	1396 ha	2,792
	Total			**7,678**

Similarly, total Cess estimated for post construction till 2046 based on the velocity of transaction for the corresponding year and type of use (built-up area) and applicable rate of cess for each type of usage (residential/commercial/office) as provided in the proposed cess rate table above has been calculated. The velocity of transactions has been assumed such that immediately after commissioning of the project higher number of transactions are expected (20%) and after a period of time this could reduce gradually towards the end of the project period (5%).

The table below gives the detailed year wise estimated revenue from cess and the total amount of fund generated uptil 2046 is Rs. 123,317 million. The Transaction Cess fund would be used to repay the debt including interest and principal.

Table 8-18 : Estimated Transaction Cess after Construction

Sr. No.	Year	Velocity of Transaction	Residential	Commercial	Office	Total Cess
		%	Rs. Million			
			@Rs.1000	@Rs.2000	@Rs.1500	
1	2016	20%	2,513	1,675	3,350	7,538
2	2017	15%	1,885	1,256	2,513	5,654
3	2018	15%	1,885	1,256	2,513	5,654
4	2019	15%	1,885	1,256	2,513	5,654
5	2020	14%	1,759	1,173	2,345	5,277
6	2021	14%	1,759	1,173	2,345	5,277
7	2022	14%	1,759	1,173	2,345	5,277
8	2023	13%	1,633	1,089	2,178	4,900
9	2024	13%	1,633	1,089	2,178	4,900
10	2025	13%	1,633	1,089	2,178	4,900
11	2026	12%	1,508	1,005	2,010	4,523
12	2027	12%	1,508	1,005	2,010	4,523
13	2028	12%	1,508	1,005	2,010	4,523
14	2029	11%	1,382	921	1,843	4,146
15	2030	11%	1,382	921	1,843	4,146
16	2031	11%	1,382	921	1,843	4,146
17	2032	10%	1,313	875	1,751	3,939

Sr. No.	Year	Velocity of Transaction	Residential	Commercial	Office	Total Cess
		%	Rs. Million			
18	2033	10%	1,247	832	1,663	3,742
19	2034	9%	1,185	790	1,580	3,555
20	2035	9%	1,126	750	1,501	3,377
21	2036	9%	1,069	713	1,426	3,208
22	2037	8%	1,016	677	1,355	3,048
23	2038	8%	965	643	1,287	2,895
24	2039	7%	917	611	1,222	2,751
25	2040	7%	871	581	1,161	2,613
26	2041	5%	827	552	1,103	2,482
27	2042	6%	786	524	1,048	2,358
28	2043	6%	747	498	996	2,240
29	2044	6%	709	473	946	2,128
30	2045	5%	674	449	899	2,022
31	2046	5%	640	427	854	1,921
	Total		**41,106**	**27,402**	**54,809**	**123,317**

Following table provides summary of revenue streams and total estimated project revenues for 2018 (first full stable year of operations), 2021, 2031 and 2041.

Table 8-19 : Summary of Project Revenue

Sr. No.	Revenue Stream	2018	2021	2031	2041
		Rs. Million /Year			
1	Fare box	8,476	12,873	26,434	52,831
2	Commercial areas at stations	45	62	102	167
3	Commercial areas at secondary buildings	894	1,292	2,104	3,427
4	Advertisement Panels	85	129	264	528
5	Transaction Cess on TOD post construction	5,654	5,277	4,146	2,482
	Total Project Revenue	**15,154**	**19,633**	**33,050**	**59,435**

9. CAPITAL COST ESTIMATION

9.1 Introduction

Capital Cost estimate for the proposed RRTS Delhi –Ghaziabad - Meerut corridor has been prepared covering the cost heads for the following areas at 2011 price levels:

- Civil works, Alignment and formation,
- Station buildings,
- E&M works,
- Depot and workshop,
- Permanent way,
- Traction,
- Signalling and telecom,
- AFCS,
- Land acquisition and R&R,
- Rolling stock and
- Miscellaneous works (spares, trainings, testing and commissioning, Utility diversions etc.)

Capital cost estimates have been prepared for the civil and systems works of the Delhi - Meerut RRTS corridor. The cost has been calculated as per route km for items spread over the alignment and per unit for items not related to route length.

All items related with alignment, whether in underground or elevated construction, like permanent way OHE, signalling and telecommunication, have been estimated on cost per km basis. Cost of underground alignment construction per route km excludes station lengths .The cost of stations and depots are estimated separately as per the initial design plans prepared.

The cost for underground stations includes cost of civil structures and architectural finishes. Similarly, cost of elevated portion includes civil work for station structures, architectural finishes, platform roofing etc.

Cost of E&M works, permanent way, power supply, signaling and telecommunication, automatic fare collection, rolling stock, have been assessed separately.

Land cost has been assessed on the basis of each segment of the land that is required. The cost of acquiring private land is only considered in the estimates for arriving final costs.

9.2 Capital Cost Estimation Basis

The capital cost of various items have been assessed on the basis of the following:

- For each system and works like Viaduct, Tunnels, Rolling Stock, Power Supply, Signals, Communications, AFC, Depots, Machinery and Plant (M&P) etc a list of items and quantities has been prepared based on the consultant's experience, traffic studies, operations simulation and alignment survey.

- The rates of different items have been assessed from market prices or rates from similar works in Indian Railways and Metro projects in India.
- For elevated viaduct, the actual BOQ has been worked out and current Delhi rates have been used to work out the cost.
- For station costs, a separate study for conceptual design and costs has been conducted.
- A suitable escalation factor has been applied to bring these estimated costs from other metro and rail projects to current price level.
- Cost of M&P has been taken from Indian Railways COFMOW purchase rates and where these are not available, from rates in other Indian Railways or Metro projects.
- Taxes & Duties such as Customs Duty, sales Tax, Works Tax, VAT, etc., wherever applicable, have been worked out on the basis of prevailing rates and included in the cost estimates separately.
- An escalation factor of 5% per year from previous costs has been assumed in arriving at costs of 2011.

9.3 Capital Cost

The overall Capital Cost for the RRTS corridor at current price level works out to Rs. 16,592.47 crore. Abstract cost of the RRTS is shown in below. Details and methodology of arriving at these costs are discussed below.

9.4 Civil Engineering Works

9.4.1. Land

For the land needed to construct the RRTS alignment, stations, depots and power sub stations, the land requirement has been kept to the bare minimum. Acquisition of private land has been minimised as far as possible. For underground and elevated alignment, no land is proposed to be acquired permanently, except small areas for locating entry/ exit structures, traffic Integration etc. Elevated alignment is proposed to be located on the central verge of the road wherever possible. Where this is not possible, minimum land corridor of about 20m width is proposed for acquisition.

Cost of Govt. land has not been accounted for in the estimate. Private land for RRTS project shall be acquired by executing agency and compensation shall be paid as per prevailing Land acquisition act. The average cost of land acquisition has been worked out at various places based on prevailing rates.

Rehabilitation Grant: Apart from the on time payment for land acquisition, we propose an annual payment equivalent to 1% of land cost to be escalated at 5% per annum to the individual land owners for the entire concession period of the project (till FY2046).

There will also be some temporary acquisition of land near the proposed alignment for construction activity and casting yards. Ground rent charges for 3 years has been provided for in project cost estimates.

Land required for Transit Oriented development has not been taken in this estimate, since it will depend on development option adopted for TOD. In the proposed business plan, land acquisition for TOD is not envisaged by Government.

9.4.2. Alignment

9.4.2.1 Underground Section

The length of underground and elevated sections of the RRTS has been calculated after a detailed survey. In the underground section the construction work will be generally done by tunnel boring machines due to the densely populated area of the alignment. Where feasible, cut and cover method will be used.

The rates adopted for cut and cover section, as well as for work to be done by T.B.M. are based on consultations with tunneling experts and cost of similar works. Suitable allowance has been made for the larger diameter tunnels for the RRTS.

9.4.2.2 Elevated Section

Most of the alignment will be on elevated via duct. The rates for construction of the elevated viaduct have been calculated through a separate viaduct design study undertaken, where the actual broad BOQ for the structures has been worked out and the local schedule of rates have been applied.

9.4.3. Stations

9.4.3.1 Underground Stations

Underground stations have to be constructed by cut and cover method. The rate proposed for stations (length 400m) includes cost of station structures, platforms, architectural finishes, etc. Provisions for electrical and mechanical works, HVAC, lifts and escalators etc., have been made separately in the station cost.

The cost for OHE, PWay, Signaling and Telecommunication, Automatic Fare Collection at stations have been taken separately in the costs of these items and have not been included in the station costs.

The station conceptual design as well as the costs have been prepared by professional architects appointed for this purpose.

9.4.3.2 Elevated Stations

Rates used for elevated stations include the works of station structures, platforms, architectural finishes, covering, etc. Provisions for electrical and mechanical works, lifts and escalators etc., have been made separately in the station cost.

The cost for OHE, PWay, Signaling and Telecommunication, Automatic Fare Collection at stations have been taken separately in the costs of these items and have not been included in the station costs.

The station conceptual design as well as the costs have been prepared by professional architects appointed for this purpose.

9.5 Depots

The RRTS corridor will have a depot cum workshop at Modipuram and a sub depot at Duhai. For each depot a layout and size of trackwork, repair sheds, stabling lines, maintenance buildings, Stores building, Administrative office, Canteen, Water supply, etc has been estimated in detail. The cost of these items are based on the schedule

of rates, the rates adopted by Indian Railway Workshops and new Metro Rails in India.

The M&P required for the depots has been assessed based on the workload. Cost of the M&P has been from Indian Railways Centre for Modernization of Workshops or where not available from COFMOW, from market costs or cost incurred in Railway and metro projects.

The cost of OHE, trackside S&T equipment has been accounted for under the heads of these items and not included in the depot cost. Some S&T equipment exclusive to the depots like internal telephone exchange, intercom, computerized attendance system and clocks etc have been taken in the depot costs. Similarly cost of depot auxiliary substation, electrical connections to M&P etc have been taken in depot costs.

9.6 Rolling Stocks

The cost of Rolling Stock has been estimated through consultations with manufacturers as well as through comparison with Metro rail coaches currently being procured in Delhi Metro. Consideration has been given to the non standard and larger size of the RRTS coaches.

9.7 Traction and Power Supply

For working out the power supply cost, the number and capacity of traction sub stations has been worked out, based on the number of trains to be run and the auxiliary load. The number and capacity of auxiliary sub stations has been based on the experience of metro stations.

The length of OHE and ring main is known from the alignment study and depot layouts. Provision has been made to cover the cost of service connection charges from Grid Sub Station to Receiving Sub Station. Cost of SCADA has also been added.

The rates for above items are based on the similar system of metro projects rates escalated to current prices. The costs have been calculated on route km basis separately for underground alignment, and elevated section as the requirement and costs are different.

9.8 Permanent Way

For underground and elevated alignment ballastless track and for depots ballasted track as well as embedded track has been proposed. The length of the track including portions in loop lines and ramps has been calculated from the alignment study done. The length of ballasted and embedded track in depots has been calculated from the depot layout.

The rates adopted for ballastless track are based on Delhi Metro and experience on other similar projects. The estimates are made to September 2011 price level. For ballasted and embedded track in depots, the rates have been taken from estimates of Indian Railways workshops.

9.9 Automatic Fare Collection

The number of gates required at each station has been worked out based on the peak hour passengers at the station. The number of other equipment like Baggage Screening Machines, Ticket Office Machines, End Cabinets, Portable Ticket Readers, Central Computer and Router at OCC, Station Computer, Networking Equipment etc has been calculated for each station. The rates for these items are based on the cost of similar works currently being undertaken in India.

9.10 Signalling and Telecommunication Works

The S&T costs include train on board equipment, trackside equipment, software development, installation and integration. The rates adopted are based on the Delhi Metro rates, with appropriate adjustments to account for stations spacing, signal blocks, communication linkages required, other equipments etc on the RRTS compared to the Metro.

9.11 General Charges and Contingencies

Considering nature of project, provision @ 5% has been made towards general charges including design charges on all items, except cost of land. Provision for contingencies @ 5% has been made on all items including general charges and land cost.

9.12 Capital Cost Estimate

9.12.1. Base Capital Cost

Cost estimates have been prepared for various items based on criteria like, Route length of the alignment, Number of units of a particular item and item being and independent entity.

The following table estimates the basic cost at 2011 levels for various heads as stated above along with the basis of estimation as well as inclusions/ exclusions.

Table 9-1 : Summary of Estimated CAPEX

Item	Description	Units	Quantity	Rate	Total
				Rs. Crore/ per Unit	Rs. Crore
1.0	**Land**				**1,656.75**
1.1	Private Land	Hectare	330.8	5.00	1,653.75
1.2	Rly Land	Hectare	0.1	0.00	0.0
1.3	Casting Yard	Hectare	25.0	0.01	3
1.4	Government land	Hectare	26.2	0.00	0.0
2.0	**Civil works, Alignment and formation (excl. Stations & Depot)**		84.02		**5,758.94**
2.1	Tunneling Work	R Km	24.20	152.86	3,699.2
2.2	Ramp - underground	R Km	1.30	47.35	61.6

Item	Description	Units	Quantity	Rate	Total
				Rs. Crore/ per Unit	Rs. Crore
2.3	Ramp - Elevated	R Km	1.58	18.52	29.3
2.4	Elevated Viaduct	R Km	53.02	30.00	1,590.5
2.5	Underground section by Cut & Cover excluding Station length	R Km	2.30	107.23	246.6
2.6	Special Spans	R Km	0.70	47.61	33.4
2.7	Underground loop lines	R Km	0.92	107.23	98.2
3.0	**Station Building (Incl. Commercial area)**		17.000		**2,393.56**
3.1	Underground Terminal station	Nos.	1.0	125	125.0
3.2	Underground Station	Nos.	5.0	207	1,036.5
3.3	Elevated Stations	Nos.	9.0	116	1,042.5
3.4	Elevated Terminal station	Nos.	2.0	95	189.6
4.0	**E&M Works**		17.000		**745.47**
4.1	Electro mechanical works including Lifts, Escalators, DG sets, UPS,TVS, ECS				
4.1.1	Underground station	Nos.	6.0	67.33	404.0
4.1.2	Elevated station	Nos.	11.0	26.68	293.5
4.1.3	At grade station	Nos.	0.0	-	-
4.2	Tunnel Ventilation	R Km	15.05	3.19	48.0
5.0	**Depot-cum-Workshop**		2.0		**205.66**
5.1	Modipuram Depot				
5.1.1	Civil works	Nos.	1.0	84.63	84.6
5.1.2	Plant and Machinery	Nos.	1.0	76.98	77.0
5.2	Duhai Depot				
5.2.1	Civil works	Nos.	1.0	24.07	24.1
5.2.2	Plant and Machinery	Nos.	1.0	19.98	20.0
6.0	**Permanent Way**				**634.04**
6.1	Ballastless track for elevated & underground alignment	R KM	93.0	6.48	602.5
6.2	Ballasted/Embedded track for at grade allignment (for Depot incl. 1.4 km for non electrical lines)	R KM	11.25	2.8	31.5
7.0	**Traction & Power Supply incl. OHE, ASS etc.**				**758.10**
7.1	Under Ground Section	R KM	31.1	8.70	270.7
7.2	Elevated & At Grade Section	R KM	71.7	6.80	487.4

Item	Description	Units	Quantity	Rate	Total
				Rs. Crore/ per Unit	Rs. Crore
8.0	**Signalling and Telecom. (incl. Depot lines)**				**755.33**
8.1	Signalling	R KM	103.1	6.34	653.3
8.2	Telecom.	No. of Stations	17.0	6	102.0
9.0	**Automatic fare collection**				**79.90**
9.1	Ticketed Stations	No. of Stations	17.0	4.7	79.9
10.0	**R & R**				**52.12**
10.1	R & R incl. Hutments and road restoration etc	R KM	104.2	0.5	52.1
11.0	**Misc. Works**				**197.74**
11.1	Utilities Relocation	R KM	104.2	0.5	52.1
11.2	Misc. civil works such as median, road signages	R KM	104.2	0.5	52.1
11.3	Barracks for Security Staff including security equipments	Nos.	17.0	0.5	8.5
11.4	Staff Quarters for O&M	Nos.	17.0	5	85.0
12.0	**Rolling Stock**				**1764.00**
12.1	EMU Coaches	Nos.	168	10.5	1,764.0
13.0	**Miscellaneous Items**				**127.15**
13.1	Training	Nos.	1	10.0	10.0
13.2	Spares	%	2.00%	3,357.3	67.1
13.3	Testing and Commissioning Costs	Nos.	1	50.0	50.0
14.0	**Total**				
14.1	Total (Including Land Cost)	Sum (1 to 13)			**15,128.8**
14.2	Total (Excluding Land Cost)	Item 14.1 Less 1			13,472.0
14.3	General Charges incl. Design charge	% of 14.2	13,472	5%	673.6
14.4	Contingency	14.1+14.3	15,802	5%	790.1
	Estimated Construction Cost on Year 2011 Basis (Excluding Land)				**14,935.72**
	Estimated Construction Cost on Year 2011 Basis				**16,592.47**

9.13 Initial CPAEX Phasing

9.13.1. Summary of Base Capital Cost

The base Capital Cost of the project at 2011 price levels including General Charges, contingency and land prices but excluding government land cost, central and state level taxes and Interest During Construction (IDC) is given in the table below:

Table 9-2 : Summary of Base Capital Cost (excluding Taxes and Duties)

Sr. No.	Components	Amount in Rs. Million
1	Land	16,567.50
2	Civil works, Alignment and formation	57,589.39
3	Overhead Station Buildings	12,320.88
4	Underground Station Buildings	11,614.76
5	E &M works	7,454.70
6	Depot cum Workshop	2,056.60
7	Permanent Way	6,340.43
8	Power Supply and Substations	7,580.96
9	Control Systems	8,352.33
10	R&R	521.18
11	Miscellaneous works	1,977.35
12	Rolling Stock	17,640.00
13	Miscellaneous Items	1,271.47
14	General Charges including design charges (@ 5% of Sr. No. 2 to 13)	6,736.00
15	Contingency (@5% of Sr. No 1 to 14)	7,901.18
	Total Base Project Cost (Sr. No 1 to 15)	**165,924.73**

9.13.2. Base Capital Cost with taxes and duties

The table below provides the details of Capital cost including central taxes (customs duty and excise duty) and state taxes (VAT).

Table 9-3 : Summary of Base Capital Cost (with Taxes and Duties)

Sr. No.	Components	Amount in Rs. Million
1	Land	16,567.50
2	Base Construction Cost (excl. land cost & General Charges and Contingency)	134,720.03
3	**Total Base Project Cost**	**151,287.53**
4	Central Taxes	**14,265.93**
a	Customs Duty	9,211.20
b	Excise Duty	5,054.73
5	Cost including Central Taxes (3+4a+4b)	165,553.46

Sr. No.	Components	Amount in Rs. Million
6	State Tax	**8,335.37**
a	Value Added Tax	8,335.37
7	Cost including State Tax (5+6a)	173,888.83
8	General Charges @5% on (7 -1)	7,866.07
9	Contingency @5% on (1+7+8)	9,087.74
	Total Cost (incl. taxes excl. IDC)	**190,842.64**

9.13.3. Initial CAPEX Phasing

The table below specifies the year wise requirement of funds for capital expenditure. For FY 2013 and FY 2017 only 2 quarters have been considered for investment purpose and all other financial years are full 12 months for implementation of the project. Base cost has been escalated at 5% year on year basis during implementation phase.

Table 9-4 : CAPEX Phasing

Sr. No.	Components	FY13*	FY14	FY15	FY16	FY17 *	Total
		Rs. Million					
1	Land	5,523	11,045	-	-		**16,568**
2	Civil works, Alignment and formation	7,958	23,108	30,961	16,006		**78,033**
3	Overhead Station buildings	1,856	5,846	8,184	4,297		**20,182**
4	Underground Station buildings	1,980	6,238	8,734	4,585		**21,538**
5	Depot-cum-Workshop	-	864	1,396	513		**2,774**
6	Power supply and substations	-	-	4,421	5,461	860	**10,742**
7	S&T (excluding onboard) and AFC	-	-	4,611	6,052	1,271	**11,934**
8	Resettlement and rehabilitation	194	407	-	-	-	**601**
9	Miscellaneous	491	1,031	1,083	1,137	597	**4,339**
10	Rolling Stock	3,609	7,579	8,078	4,304	-	**23,570**
11	Total	21,611	56,119	67,469	42,356	2,728	**190,282**
12	Other charges(General Charges & contingency)	2,022	5,513	6,959	4,587	310	**19,391**
13	IDC	-	-	407	1,445	838	**2,690**
14	Margin money	-	-	-	-	379	**379**
	Total capital cost	**23,632**	**61,631**	**74,835**	**48,387**	**4,256**	**212,741**

9.14 Additional Investments

Based on traffic projections, additional investment in rolling stock shall be required for 2022, 2031 and 2041. Additional investments at 2011 price level and it includes

prevailing taxes and duties (as given in the table below) suitably adjusted for inflation rate of 5% year on year basis have been provided in the model.

Table 9-5 : Additional Investments

Particulars/ Year	2022	2031	2041
Additional Rolling stock			
Number of trains	18	66	27
Cost in Rs. Million	2,232	8183	3,348

9.15 Replacement Cost

At the end of 20 years from COD, it is proposed for an investment of Rs. 13,922 Million (about 25% of the total capital cost) towards replacement cost. This amount includes prevailing taxes and duties at the base price level. Following components are proposed to be replaced for efficient functioning of the system.

- E&M works for stations
- Lifts & Escalators for Stations
- E&M works for Depot cum Workshop
- Depot Plant and Machinery
- Power Supply and Sub- stations
- S&T and AFC

The replacement costs needs to be accounted for inflation adjustment at the rate of 5% year on year, which has been provided for in the model.

10. OPERATION & MAINTENANCE COST ESTIMATION

10.1 Introduction

The Operation & Maintenance costs can be divided into three major parts:

a) Maintenance Cost including spare parts & consumables
b) Manpower Cost
c) Energy Cost

10.2 Maintenance Cost

Annual maintenance cost is provided for repair and maintenance of the facilities developed and spares parts, consumables required for the Project during the life span of the Project. The cost of such material which is consumed annually depends on a lot of factors such as the design of the equipment, the intensity of usage, the maintenance philosophy, the manufacturer's recommendations, renewal plans etc. The cost has been adopted based on experience in similar projects in India.

For this purpose maintenance cost has been taken at 0.80% of total capital cost of civil structure and system. The estimated maintenance cost for the first full year of operated (2018) is at Rs. 1,771 Million. Base annual maintenance costs (Rs. 1,259 Million) have been escalated for inflation at the rate of 5% year on year basis from 2011. Further, incremental maintenance cost for additional investments proposed during the project life has also been considered at the same rate as above. Year wise annual maintenance cost is set out below.

Table 10-1 : Estimated Maintenance Cost

Sr. No.	Year	Annual Maintenance Cost
		Rs. Million / Year
1	2018	1,771
2	2021	2,060
3	2031	3,486
4	2041	6,145

10.3 Energy Cost Estimation

Estimation of energy consumption for RRTS has been worked for following:

a) Traction Consumption and Cost for the Route
b) Traction Consumption and Cost for Depots (Modipuram & Duhai)
c) Auxiliary Power Consumption and Cost for Stations
d) Auxiliary Power Consumption and Cost for Depots (Modipuram & Duhai)

The number of trains to be run on the RRTS has been determined through a detailed operations simulation study. The gross weight of a coach was taken as 64 tonnes

including tare weight and passenger weight. Thereafter the total weight of a 6 coach and 9 coach train was determined to calculate energy consumption.

The annual kilometres earned by the trains has been calculated in the operations study. Therefore the Gross Tonne-Km earned by the trains is known. The specific energy consumption for the RRTS coach has been assessed as 55 KWH per 1000 GTKM. This is based on the assessment given by coach manufacturers, the Indian Railways specification for new EMU coaches, the SEC of TGV trains and the SEC of Metro trains in Delhi. Consideration has been given to the fact that there is very little coasting and a lot of movement from underground to elevated track.

Based on GTKM earned by the trains and Specific Energy Consumption rate adopted, energy consumed in KWH was estimated.

Capacity augmentation has been proposed in 2031 due to the increase in additional rolling stock to cater the demand. The power supply cost is taken as Rs. 4.50 per unit for the RRTS for calculation of cost of traction energy. The annual energy consumption is estimated at 263.8 million units for 2018 and 406.6 million units for 2041.

Table 10-2: Estimation of Traction Cost for the Alignment

Particulars	Units	2018	2021	2031	2041
Weight of train	Ton	384	384	576	576
Specific Energy Consumption	Kwh/1000 GTKM	55	55	55	55
Energy Cost	Rs. /kwhr	4.5	4.5	4.5	4.5
Total Kms earned by all Trains	Km/year	10,110,500	10,391,075	10,110,500	10,391,075
1000GTKM per year	1000 GTKM/ year	3,882,432	3,990,173	5,823,648	5,985,259
Energy Consumed per year	Units	213,533,760	219,459,504	320,300,640	329,189,256
With 5% loss, .85 pf per year	Units	263,776,998	271,097,034	395,665,496	406,645,552
Traction Cost per year	**Rs. Million**	**1187.0**	**1219.9**	**1780.5**	**1829.9**

Certain amount of traction power will also be consumed in the depots. Knowing the total number of trains and the kms moved by them in the depots, gives us the GTKM for depots. Each train is expected to run around 5 km per day (for 20 trains-modipuram & for 9 trains – Duhai) the total energy per year has been worked out in the table below for each depot separately. For depots the SEC has been taken as 40 since the trains move at slow speed and the depot traction power has thus been calculated. The total estimated annual energy cost for Modipuram Depot is Rs. 2.3 million for the year 2018 and Rs. 3.5 million for the year 2031.

Table 10-3 : Estimation of Traction Cost for Modipuram Depot

Particulars	Units	2018	2021	2031	2041
Weight of empty train		48	48	48	48
Specific Energy Consumption for Depot	Kwh/1000 GTKM	40			
GTKM per day for 20 trains in depot	GTKM/day	28,800	28,800	43,200	43,200
1000 GTKM per year in depot	1000GTKM/ year	10,512	10,512	15,768	15,768
Energy per year in depot	Units	420,480	420,480	630,720	630,720
With 5% loss, .85 pf per year	Units	519,416	519,416	779,125	779,125
Traction Cost per year	**Rs. Million**	**2.3**	**2.3**	**3.5**	**3.5**

The total estimated annual energy cost for Duhai Depot is Rs. 1.1 million for the year 2018 and Rs. 1.6 million for the year 2031.

Table 10-4 : Estimation of Traction Cost for Duhai Depot

Particulars	Units	2018	2021	2031	2041
Specific Energy Consumption for Depot	Kwh/1000 GTKM	40			
Weight of empty train	Ton	48	48	48	48
GTKM per day for 9 trains in depot	GTKM/day	12960	12960	19440	19440
1000 GTKM per year in depot	1000GTKM/ Year	4730	4730	7096	7096
Energy per year in depot	Units	189,216	189,216	283,824	283,824
With 5% loss, .85 pf per year	Units	233737	233737	350606	350606
Energy Cost per year	**Rs. Million**	**1.1**	**1.1**	**1.6**	**1.6**

For auxiliary power consumption, the following assumptions have been made:

- Each elevated station will consume 0.35 MW of electricity, going up to 0.5 MW in 2041
- Each underground station will consume 2MW going up to 2.5 MW in 2041
- Modipuram depot will consume 2MW going up to 2.5MW in 2041
- Duhai depot will consume 1 MW going up to 1.5MW in 2041
- The Tunnel Ventillation System will consume 0.5 MW per Km of tunnel

It is estimated that the station auxiliary system will work at 80% of its capacity during 18 hours of train working and at 20% during the non train working hours. Similarly, in

depots the consumption will be 80% of the installed capacity during the 6 hours of non train working, when maintenance work will be in full swing. For the remaining 18 hours, the energy consumed will be 60% of the installed capacity since only some repair activities and major schedules will be done.

The energy consumed by the stations, TVS and depots is thus assessed and converted to cost based on unit rate of Rs 4.50 for auxiliary power.
As discussed above, auxiliary power for underground and elevated stations has been estimated. The total annual energy cost for year Rs. 739.80 million and Rs. 1029.9 million for the year 2018 and year 2041 respectively. Detailed working of auxiliary power is as given below.

Table 10-5 : Estimation of Auxiliary Power for Stations

Particulars	Units	2018	2021	2031	2041
Elevated station installed capacity (11 nos.)	MW/st.	0.35	0.40	0.40	0.50
UG station installed capacity (6 nos.)	MW/st.	2.00	2.25	2.25	2.50
Total station installed capacity	MW	15.85	17.90	17.90	20.50
Tunnel length requiring ventilation	Km	15.04	15.04	15.04	15.04
TVS power requirement per KM	MW	0.50	0.50	0.50	0.50
Total TVS requirement	MW	7.5230	7.523	7.523	7.523
Total installed capacity	MW	23.37	25.42	29.94	32.54
Consumption for 18 hours	MWH	336.57	366.09	431.09	468.53
Consumption for 6 hours	MWH	28.05	30.51	35.92	39.04
Total consumption per day	MWH	364.62	396.59	467.01	507.57
Total consumption per year	KWH	133,085,862	144,758,562	170,460,139	185,264,539
With 5% losses and .85pf	Units	164,400,182	178,819,400	210,568,407	228,856,195
Energy consumed per year	Units	164,400,182	178,819,400	210,568,407	228,856,195
Energy Cost per year	**Rs. Million**	**739.8**	**804.7**	**947.6**	**1029.9**

Demand for auxiliary power for two depots has been estimated in the table set out below. The estimated power consumption cost is Rs. 95 million and 118.70 million for 2018 and 2031 respectively.

Table 10-6 : Estimation of Auxiliary Power at Modipuram & Duhai Depot

Particulars	Units	2018	2021	2031	2041
Installed capacity	MW	3	3	3.75	3.75
Use at 80% capacity at night for 6 hours	MWH	14.4	14.4	18	18
Use at 60% capacity at night for 18 hours	MWH	32.4	32.4	40.5	40.5
Consumption per day	MWH	46.8	46.8	58.5	58.5
Consumption per year	MWH	17082	17082	21352	21352
Consumption per year	Units	17082000	17082000	21352000	21352000
With 5% loss, .85 pf per year	Units	21,101,294	21,101,294	26,376,618	26,376,618
Energy cost	**Rs. Million**	**95.0**	**95.0**	**118.70**	**118.70**

Based on the detailed estimation given above, the total annual energy cost is estimated at Rs. 2025.2 million for 2018 and Rs. 2983.6 million for 2041 and a break-up of the same is provided in the table below.

Table 10-7 : Summary of Base Energy Costs

Sr. No.	Description	2018	2021	2031	2041
		Rs. Million			
1	Traction Cost – Route	1187.0	1219.9	1780.5	1829.9
2	Traction Cost – Modipuram Depot	2.3	2.3	3.5	3.5
3	Traction Cost – Duhai Depot	1.1	1.1	1.6	1.6
4	Auxiliary power for Stations	739.8	804.7	947.6	1029.9
5	Auxiliary power - Depots	95.0	95.0	118.70	118.70
	Total Energy Cost	**2025.2**	**2123**	**2851.9**	**2983.6**

The base energy cost has been indexed at 3% year on year from the base year 2011 towards increase in energy charges.

10.4 Manpower Cost Estimation

The total number of staff in different categories namely train operation, maintenance staff at depots and station staff at each location has been assessed for the RRTS. This assessment is based on contemporary staffing pattern on Metro Rail systems, suitably modified to account for the lesser number of stations on the RRTS The number of train drivers has been calculated based on the duty hours and the number of trains to be run. The staff requirement is estimated for the initial phase (FY 2017) and subsequently for every 5 years from COD an incremental increase in manpower is considered at 10%. Accordingly, the number of staff per km is estimated about 24 persons (2018) and the total estimated manpower cost is at Rs. 961 Million per year

based on the constant price (i.e. 2011 base year price). The average manpower cost per staff is worked out at Rs. 28,313 per year based on 2011 price level.

Further an adjustment has been made year on year basis at the rate of 8% from the base year. For the first full year (i.e. 2018) of operation the annual estimated cost is about Rs. 1,647 Million. Year wise estimated annual manpower cost is as given below.

Table 10-8 : Estimated Manpower Cost

Sr. No.	Year	Manpower Cost
		Rs. Million / Year
1	2018	1,647
2	2021	2,282
3	2031	5,962
4	2041	15,575

10.5 Total Operation and Maintenance Cost

The total estimated Operation and Maintenance cost is set out below.

Table 10-9 : Estimated O&M Cost

Sr. No.	Year	Maintenance Cost	Energy Cost	Manpower Cost	Total
		Rs. Million			
1	2017	872	1,251	789	2,911
2	2018	1,771	2,491	1,647	5,909
3	2019	1,859	2,565	1,779	6,204
4	2020	1,952	2,642	1,921	6,516
5	2021	2,060	2,853	2,282	7,196
6	2022	2,195	2,939	2,465	7,598
7	2023	2,305	3,027	2,662	7,994
8	2024	2,420	3,118	2,875	8,413
9	2025	2,541	3,211	3,105	8,857
10	2026	2,668	3,308	3,689	9,664
11	2027	2,801	3,407	3,984	10,192
12	2028	2,941	3,509	4,303	10,753
13	2029	3,088	3,614	4,647	11,349
14	2030	3,243	3,723	5,019	11,984
15	2031	3,486	5,151	5,962	14,598
16	2032	3,914	5,305	6,439	15,659
17	2033	4,110	5,464	6,954	16,529
18	2034	4,316	5,628	7,510	17,455
19	2035	4,532	5,797	8,111	18,440
20	2036	4,758	5,971	9,636	20,365
21	2037	4,996	6,150	10,407	21,553
22	2038	5,246	6,335	11,240	22,820
23	2039	5,508	6,525	12,139	24,172
24	2040	5,783	6,721	13,110	25,614
25	2041	6,145	7,242	15,575	28,961

Sr. No.	Year	Maintenance Cost	Energy Cost	Manpower Cost	Total
		Rs. Million			
26	2042	6,680	7,459	16,821	30,960
27	2043	7,014	7,683	18,166	32,863
28	2044	7,365	7,913	19,620	34,898
29	2045	7,733	8,151	21,189	37,073
30	2046	8,120	8,395	25,173	41,688

11. PROJECT STRUCTURING & VIABILITY

11.1 Recent Project Cases

Recent projects already commissioned and under construction have been used as a template to understand the typical project structures prevalent in the industry in India. Specific cases are set out below:

Table 11-1 : Recent Project Deals in India

Projects	GOI + GOS[1] (%)	SLW[2] (%)	Pvt. Sector	Length (km)	Project Cost	Cost /km
	(%)	(%)	(%)	km	Rs. Crore	Rs. Crore/km
DMRC Phase I	40	60	Nil	65	10,571	163
Phase 2	40	46	Nil	124.3	18,894	152
Phase 3 (option 1 & 2)	50+6	(int. 14) 40	Nil	69.6	21,161	304
	40+6	(int. 4) 50	Nil			
Airport Rail link, Delhi	54	Nil	46	22.7	3,869	170
Bangalore	55	45	Nil	33	6,395	194
Chennai	40.8	59.2	Nil	45	1,460	324
Kolkata	55	45	Nil	13.8	4,676	339
Mumbai L1	28.1	Nil	71.9	11	2,356	214
Mumbai L2	19.8	Nil	80.9	32	8,250	258

11.2 Role of State Government

State governments have taken an aggressive stand in implementing transport infrastructure projects and such stand has been very well supported by the Central Government in pushing through these projects either by way of necessary legislation, land acquisition, equity commitments.

11.3 Role of NCRPB

We understand that NCRPB has been instrumental in signing of MoUs with various states government, besides Ministry of Urban Development, Govt. of India (MoUD) and Ministry of Railways for making equity contribution to the RRTS project. Further, equity contributions are expected to be made in a company referred to as NCR Transport Company or say (“NCRTC”) for the purpose of this report.

[1] Respective state government
[2] Soft Loan Provided by a Multi-lateral agency

NCRTC is expected to be the holding company of all RRTS project and to our understanding to have an initial corpus of Rs. 100 crores shared in the following manner:

11.4 Role of NCRPB

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NCRTC is expected to be the holding company of all RRTS project and to our understanding to have an initial corpus of Rs. 100 crores shared in the following manner:

Table 11-2 : NCRTC Shareholding Pattern

Sl. No.	Name of the Entity	Percentage (%)
1.	MoUD, Govt. of India + NCRPB	25
2.	Ministry of Railways + Govt. of India	25
3.	Govt. of National Territory of Delhi	12.5
4.	State Govt. of Uttar Pradesh	12.5
5.	State Govt. of Haryana	12.5
6.	State Govt. of Rajasthan	12.5
	Total	**100**

11.5 NCRTC SPV for Delhi – Meerut Structure

Each of the RRTS project can be developed through subsidiary of NCRTC where respective holding amongst state governments could be split based on project specific details. Therefore potential equity contributions could be as set out below:

Table 11-3 : Equity Contribution Structure of Delhi – Ghaziabad – Meerut Project

Sl. No.	Name of Entity	Percentage (%)
1.	MoUD, Govt. of India + NCRPB	25
2.	Ministry of Railways + Govt. of India	25
3.	Govt. of National Territory of Delhi and State Govt. of Uttar Pradesh	50
	Total	**100**

The contribution of GNCTD and GoUP could be split potentially made with following options:

a) In terms of route length

Table 11-4 : Break-up of Base Cost between States in terms of Route Length

Sr. No	States	Route Length	% Share in total project	% Share in 50%
		Km	%	%
1	GNCTD	10.40	11.5%	5.8%
2	Uttar Pradesh	78.20	88.5%	44.2%
	Total	**90.20**	**100%**	**50%**

b) In terms of investment

Table 11-5 : Break-up of Base Cost between States in terms of Investment

Sr. No	States	Base Cost in terms of Investment*	% Share in total project	% Share in 50%
		Rs. Crores	%	%
1	GNCTD	2,997	18.1%	9.03%
2	Uttar Pradesh	13,595	81.9%	40.97%
	Total	**16,592**	**100%**	**50%**

Note: * Base cost is based on base price level which includes land cost and excludes taxes and duties.

Share of base project cost between states have been prepared based on prorate basis using route length as given in table above. In case of share of project cost based on investment, common facilities such as depot, land for depot, singaling & telecom, permanent way, R&R rolling stock and Miscellaneous works have been taken on prorate basis and station buildings, E&M works, civil, alignment and formation and etc have been taken on actual basis.

c) **In terms of Shareholding in the Company**

Table 11-6 : Shareholding Pattern in NCRTC

Sl. No.	States	Percentage (%) Share in NCRTC
1.	Govt. of National Territory of Delhi	12.5%
2.	State Govt. of Uttar Pradesh	12.5%
	Total	**50%**

This leaves 25% balance to be picked up by these state governments or any other entity.

11.6 Role of Lenders

Multi-lateral funding agencies such as JICA, World Bank and ADB have shown keen interest in funding these projects. These projects are typically backed by central government guarantees towards repayment. Typically the loan repayment could be done from the project company, however, the exchange rate risk is taken on by the central government in such debt financing deals.

The project of this size would require, ideally soft loan from a multi lateral institution on attractive terms such as a loan paid of 20 to 30 years with interest rate less than 2%. We believe that the project could obtain atleast 40% of the construction cost at soft loan from suitable multi lateral funding agency e.g. World Bank, JICA and ADB with exchange rate risk typically borne by Government of India.

11.7 Role of Private Sector

Private sector as the concessionaire have been fairly active in the Indian market in being part of these projects on reasonable commercial terms. Some of the projects have been successfully bid out using land banks provided as part of the project, such as Hyderabad Metro project. Other projects have used the distinction of basic infrastructure costs and rolling stock required for the project in order to enable the private sector participation, besides use of some commercial development.

DIMTS has carried out analysis for structuring the project under the PPP frame work, wherein the project can be developed under a suitable PPP frame work. The total life cycle investment in the project is Rs 196,679 Million.

Based on financial analysis undertaken private sector would be in a position to contribute 25-40% of the initial cost of construction, besides undertaking several other project responsibilities.

11.8 Role of Division between Private Sector & Government (or say NCRTC)

Based on technical analysis carried out, it is believed that the project elements that could be split between government and private sector are set out in the table below:

Table 11-7 : Project Components – Government vs Private Sector

Sr. No	Project Components	Total	Government	Private Sector
		Rs. Million		
1	Land, R&R, Utility shifting & Misc. works	**19,066**	19,066	-
2	Civil works, Alignment and formation	**57,589**	57,589	-
3	Station Building	**23,936**	9,802	14,134
4	E&M Works	**7,455**	4,520	2,935
5	Depot-cum-Workshop	**2,057**	1,087	970
6	Permanent Way	**6,340**	6,340	-
7	Traction & Power Supply incl. OHE, ASS etc.	**7,581**	7,581	-
8	Signalling and Telecom.	**7,553**	-	7,553
9	Automatic fare collection	**799**	-	799
10	Rolling Stock	**17,640**	-	17,640
11	Miscellaneous Items	**1,271**	-	1,271
12	General Charges incl. Design charge	**6,736**	4,471	2,265
13	Contingency	**7,901**	5,523	2,378

Sr. No	Project Components	Total	Government	Private Sector
		Rs. Million		
	Total Base Construction Cost	**165,925**	**115,979**	**49,946**
	% of Initial Investment	**100%**	**69.90%**	**30.10%**
	% of Total Life Cycle Investment	**100%**	**58.97%**	**41.03%**

From the above analysis we suggest that about 70% of the initial construction cost would need to be contributed by the government or multilateral financial institutions. It would be prudent to, therefore split the project to deliver optimum project structuring wherein a government entity could raise fund from Financial Institutions and its own sources with about 30% of project cost from private sector investment.

11.9 Project Structure

The specific role of SPV which could be launched by NCRTC and the role of private sector based on analysis provided in the previous section is being setout in the following paragraphs.

It is proposed that the project implementation is taken by way of splitting the project in the following two SPVs:

a) RRTS Delhi-Meerut Infrastructure Limited (“DM Infraco”)
b) RRTS Delhi-Meerut Rolling stock Limited (“DM Rollco”)

11.9.1. DM Infraco

DMInfraco can be responsible for undertaking project activities as set out in table above marked as Government Sector in the Table in previous section. The share holders of DMInfraco could be as set out below:

Table 11-8 : NCRTC Shareholding Pattern

Sl. No.	Name of the Entity
1.	MoUD, Govt. of India + NCRPB
2.	Ministry of Railways + Govt. of India
3.	Govt. of National Territory of Delhi and State Govt. of Uttar Pradesh

DMInfraco could take up implementation of earmarked project activities from capitalization provided by the various government entities such as the central government and the state governments. Further, the DMInfraco could borrow money from multi-lateral financial institutions with suitable government guarantees, since multi-lateral financial institutions typically request for such guarantees as well as the fact that they would find it more convenient to fund a 100% government owned company as compared to a company with private sector majority holding.

The revenue of DMInfraco would be primarily from cess from ToD areas. In order to ensure high level of transparency in the transaction of these projects in long term of nature, it is suggested that specific benefits from ToD arising in the project not accrue to DMRollco.

The funds borrowed from multi lateral financial institutions could be paid through revenues collected as cess from ToD areas. The equity holders could keep surplus from ToD cess plus interest earned after adjustment towards loan repayment to lenders to the DMInfraco. Dividends and surplus retained by DMinfraco can be paid back to NCRTC for development of additional projects in the future.

11.9.2. DM Rollco

DMRollco can be responsible for undertaking project activities as set out in table above marked as Private Sector in the Table in previous section.

Revenue from DMRollco shall be primarily fare box revenue, revenue from rentals at stations and commercial development at the stations and adjacent area and advertisement etc. DMRollco will be required to undertake initial capital investment on rolling stock, signaling and elevated stations above ground.

Besides the initial investment DMRollco shall required taking up of all operation and maintenance cost as well as making additional investments and replacements of equipment required from time to time.

In order to obtain a reasonable level of control, it is suggested that 10% of DMRollco is held by DMInfraco with atleast with 2-3 Directors from equity holder from DMInfraco.

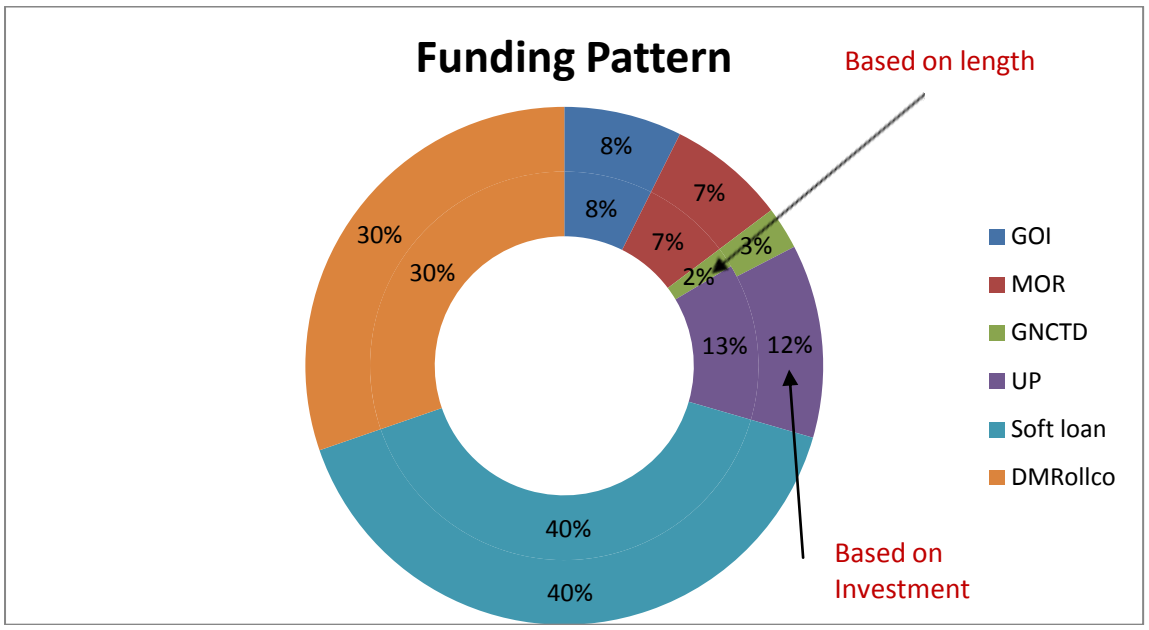
11.10 Funding Pattern

Following the project structure as suggested above, the actual funding required upto project commissioning for the project considering the central and state govt taxes, escalation in capital cost during construction period, IDC and margin money is presented in table below:

Table 11-9 : Investment Break-up – Full Project Cost

Sr. No	Entities	Investment based on length		Contribution based on Initial Investment	
		%	Rs. Crore	%	Rs. Crore
	Investments by DMInfraco				
1	MoUD, Govt. of India + NCRPB	7.37%	1,568	7.37%	1,568
2	Ministry of Railways + Govt. of India	7.37%	1,568	7.37%	1,568
3	Govt. of National Territory of Delhi	1.70%	362	2.65%	564
4	State Govt. of Uttar Pradesh	13.04%	2,774	12.09%	2,571
	Total	**29.48%**	**6,271**	**29.48%**	**6,271**
	Soft Loan	**40.23%**	**8,559**	**40.23%**	**8,559**
	Investments by DMRollco				
	Private Sector	**30.29%**	**6,444**	**30.29%**	**6,444**
	Total	**100.00%**	**21,274**	**100.00%**	**21,274**

The aforesaid excludes the project funding required for additional investments in future as well replacement costs associated with the project. These costs shall be required to be incurred by the DM Rollco.



11.11 Project Profit and Loss Statement

The projected profit and loss statement is presented below.

Table 11-10 : Projected Profit and Loss Statement for key years

Sr. No.	Description	FY18	FY19	FY20	FY21	FY31	FY41	FY46
A	**Revenue**							
1	Fare box – Full Fare	6,736	8,306	9,218	10,230	21,008	41,986	59385
2	Fare box- Concessional Fare	1,740	2,146	2,381	2,642	5,426	10,845	15339
	Total Fare box revenue	**8,476**	**10,452**	**11,599**	**12,873**	**26,434**	**52,831**	**74724**
3	Revenue from rentals	45	55	59	63	102	167	213
4	Revenue from Property development	894	1,143	1,227	1,292	2,104	3,427	4374
5	Revenue from advertisement rights	85	105	116	129	264	528	747
6	TOD Cess	5,654	5,654	5,277	5,277	4,146	2,482	1921
	Total Revenue	***15,154***	***17,408***	***18,279***	***19,633***	***33,051***	***59,435***	***81979***
B	**Expenses**							
1	Maintenance Cost	1,771	1,859	1,952	2,060	3,486	6,145	8120
2	Manpower Cost	1,647	1,779	1,921	2,282	5,962	15,575	25173
3	Energy Cost	2,491	2,565	2,642	2,853	5,151	7,242	8395
4	Rehabilitation Grant	233	244	257	269	439	715	912
	Total Operating Expenses	***6,141***	***6,448***	***6,772***	***7,465***	***15,037***	***29,676***	***42600***
5	EBITDA	9,012	10,960	11,507	12,168	18013	29759	39379

Sr. No.	Description	FY18	FY19	FY20	FY21	FY31	FY41	FY46
6	Depreciation	5,318	5,318	5,318	5,342	4540	2041	2038
7	EBIT	3,694	5,642	6,189	6,826	13473	27718	37341
8	*Interest (long & short term)*	1,766	1,722	1,655	1,589	900	986	821
9	PBT	1,928	3,920	4,533	5,236	12573	26732	36520
10	*Income Tax*	386	784	907	1,048	2,567	8,080	11,780
11	**PAT**	**1,542**	**3,136**	**3,626**	**4,189**	**10,005**	**18,652**	**24,740**

11.12 Project Cash flow analysis

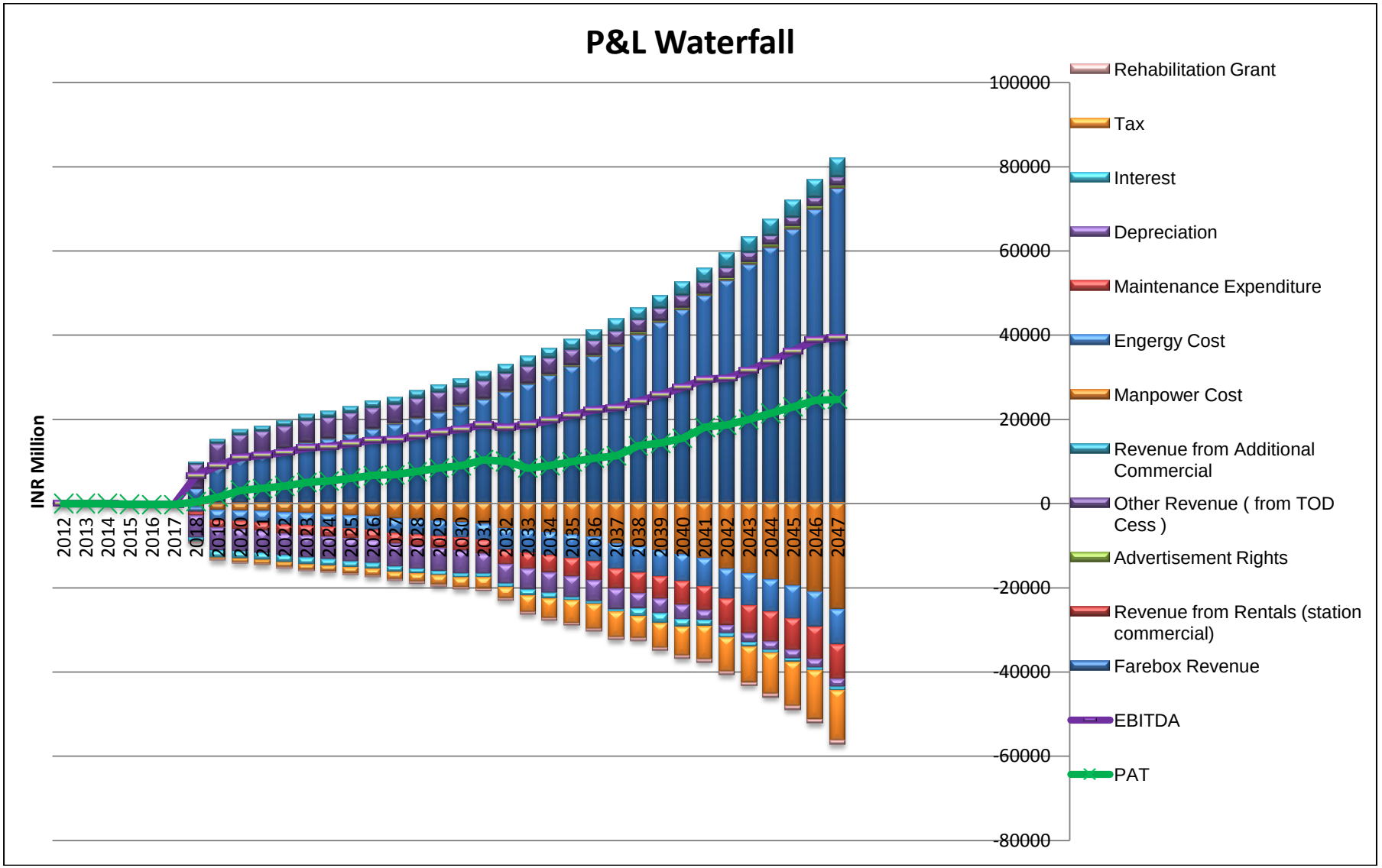
The estimation of the internal rate of return for the project is based on cash flow projected for the concession period for the project.

Following table presents the calculated Project and Equity Internal Rate of Return.

Table 11-11 : Results

Sr. No.	Description	Value (%)
1	Project IRR (pre-tax)	5.66%
2	Project IRR (post-tax)	4.25%
3	Equity IRR (DMRollco)	15.85%

The table below presents for the key years the cash inflow and outflow for the project.


P&L Waterfall
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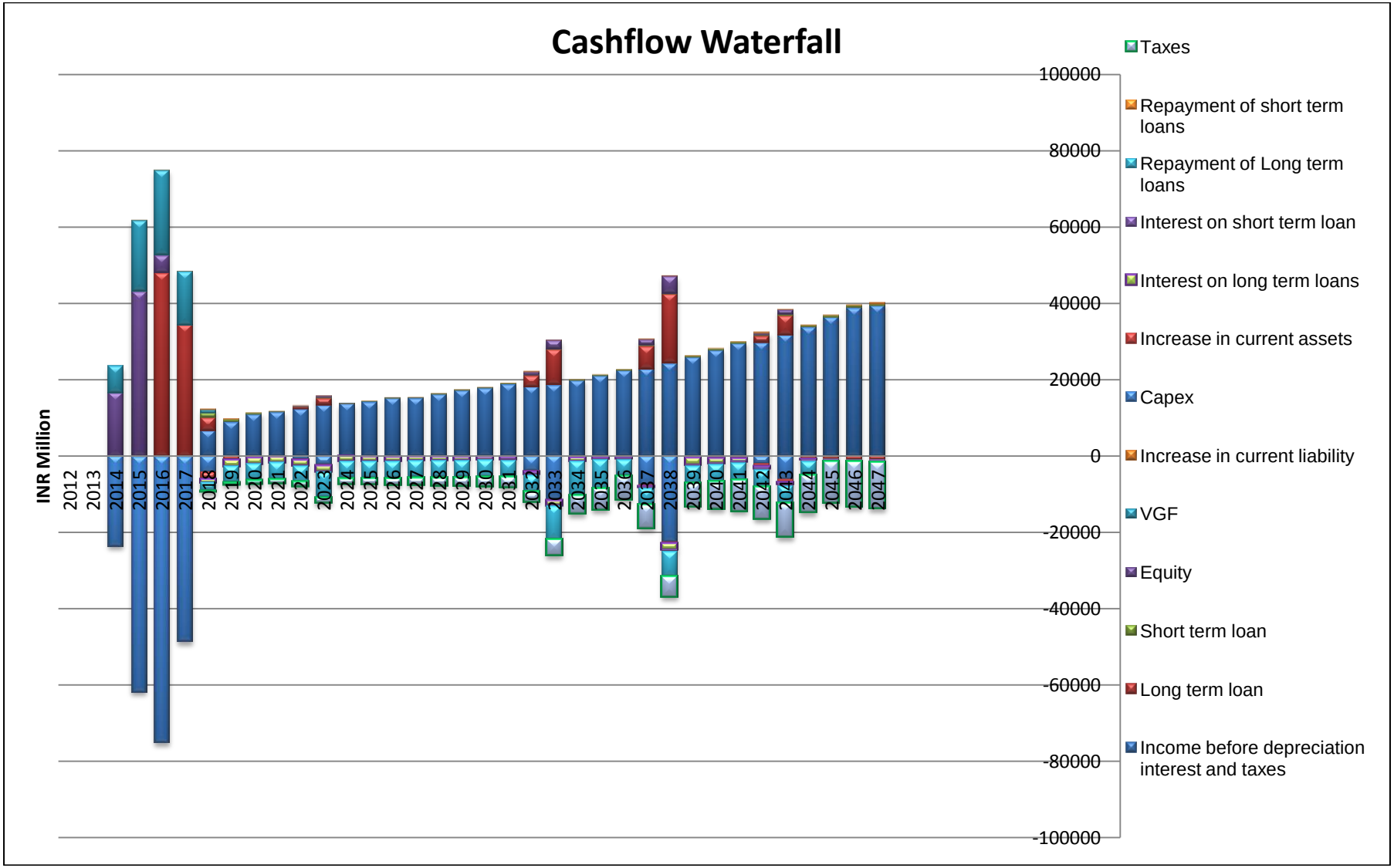
Rehabilitation Grant
Tax
Interest
Depreciation
Maintenance Expenditure
Engergy Cost
Manpower Cost
Revenue from Additional Commercial
Other Revenue (from TOD Cess)
Advertisement Rights
Revenue from Rentals (station commercial)
Farebox Revenue
EBITDA
PAT


Cashflow Waterfall
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-100000
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Taxes
Repayment of short term loans
Repayment of Long term loans
Interest on short term loan
Interest on long term loans
Increase in current assets
Capex
Increase in current liability
VGF
Equity
Short term loan
Long term loan
Income before depreciation interest and taxes

Table 11-12 : Calculation of Project IRR (Pre-tax)

Sr. No.	Description	FY13	FY14	FY15	FY16	FY17	FY21	FY22	FY31	FY32	FY36	FY37	FY41	FY46
A	**Inflow**													
1	PBT	-	(191)	(201)	(211)	489	5,236	6,265	12,573	12,383	17,311	18,837	26,732	36,520
2	Interest	-	-	-	-	902	1,589	1,566	900	1,438	611	1,985	986	821
3	Depreciation	-	-	-	-	5,318	5,342	5,416	4,540	4,902	4,902	3,475	2,041	2,038
4	**Total Inflow**	**-**	**(191)**	**(201)**	**(211)**	**6,709**	**12,168**	**13,247**	**18,013**	**18,723**	**22,824**	**24,297**	**29,759**	**39,379**
5	**Outflow**													
6	Capital Investment	(23,632)	(61,631)	(74,835)	(48,387)	(4,256)	(772)	(2,317)	(3,806)	(11,418)	(7,506)	(22,518)	(2,092)	-
	IDC	-	-	407	1,445	838	-	-	-	-	-	-	-	-
	Total Outflow	**(23,632)**	**(61,631)**	**(74,428)**	**(46,943)**	**(3,417)**	**(772)**	**(2,317)**	**(3,806)**	**(11,418)**	**(7,506)**	**(22,518)**	**(2,092)**	**-**
	Net Flow	**(23,632)**	**(61,823)**	**(74,629)**	**(47,154)**	**3,291**	**11,396**	**10,930**	**14,207**	**7,306**	**15,318**	**1,779**	**27,667**	**39,379**
	Project IRR (pre -tax)	**5.66%**												

Table 11-13 : Calculation of Project IRR (post –tax)

Sr. No.	Description	FY13	FY14	FY15	FY16	FY17	FY21	FY22	FY31	FY32	FY36	FY37	FY41	FY46
A	**Calculation of Project IRR**													
I	**Inflow**	-	(191)	(201)	(211)	391	4,189	5,012	10,005	8,422	11,362	13,771	18,652	24,740
1	PAT	-	-	-	-	902	1,589	1,566	900	1,438	611	1,985	986	821
2	Interest	-	-	-	-	5,318	5,342	5,416	4,540	4,902	4,902	3,475	2,041	2,038
3	Depreciation	**-**	**(191)**	**(201)**	**(211)**	**6,611**	**11,120**	**11,993**	**15,446**	**14,763**	**16,875**	**19,231**	**21,679**	**27,600**
	Total Inflow													
II	**Outflow**													
1	Capital Investment	(23,632)	(61,631)	(74,835)	(48,387)	(4,256)	(772)	(2,317)	(3,806)	(11,418)	(7,506)	(22,518)	(2,092)	-
2	IDC	-	-	407	1,445	838	-	-	-	-	-	-	-	-
	Total Outflow	**(23,632)**	**(61,631)**	**(74,428)**	**(46,943)**	**(3,417)**	**(772)**	**(2,317)**	**(3,806)**	**(11,418)**	**(7,506)**	**(22,518)**	**(2,092)**	**-**
	Net Flow	**(23,632)**	**(61,823)**	**(74,629)**	**(47,154)**	**3,194**	**10,348**	**9,676**	**11,640**	**3,345**	**9,369**	**(3,287)**	**19,587**	**27,600**
	Project IRR (post -tax)	**4.25%**												

Table 11-14 : Calculation of Equity IRR (DMRollco)

Sr. No.	Description	FY13	FY14	FY15	FY16	FY17	FY21	FY22	FY31	FY32	FY36	FY37	FY41	FY46
A	**Equity IRR Calculation**													
	Inflow													
1	PAT	-	(191)	(201)	(211)	391	4,189	5,012	10,005	8,422	11,362	13,771	18,652	24,740
2	Interest	-	-	-	-	5,318	5,342	5,416	4,540	4,902	4,902	3,475	2,041	2,038
3	Repayment	-	-	-	-	2,140	4,280	6,751	4,280	8,816	4,280	6,676	4,537	-
	Total Inflow	**-**	**(191)**	**(201)**	**(211)**	**7,849**	**13,811**	**17,178**	**18,825**	**22,140**	**20,544**	**23,922**	**25,230**	**26,778**
1	*Equity Contribution*	**(16,564)**	**(43,197)**	**(4,676)**	**-**	**(0)**	**(154)**	**(463)**	**(761)**	**(2,284)**	**(1,501)**	**(4,504)**	**(418)**	**-**
	Net flow	**(16,564)**	**(43,389)**	**(4,877)**	**(211)**	**7,849**	**13,656**	**16,715**	**18,064**	**19,857**	**19,042**	**19,419**	**24,812**	**26,778**
	Equity IRR (DMRollco)	**15.85%**												

11.13 Debt Servicing

The debt servicing of the soft loan can be under taken from the development cess on TOD levied on sale of built up area as described in the Revenue estimation chapter.

The table below provides the Net Present Value (@10% discount factor) of the revenues generated from TOD cess and principal and interest repayment of the soft loan from the multilateral agencies.

Table 11-15 : Projected Profit and Loss Statement

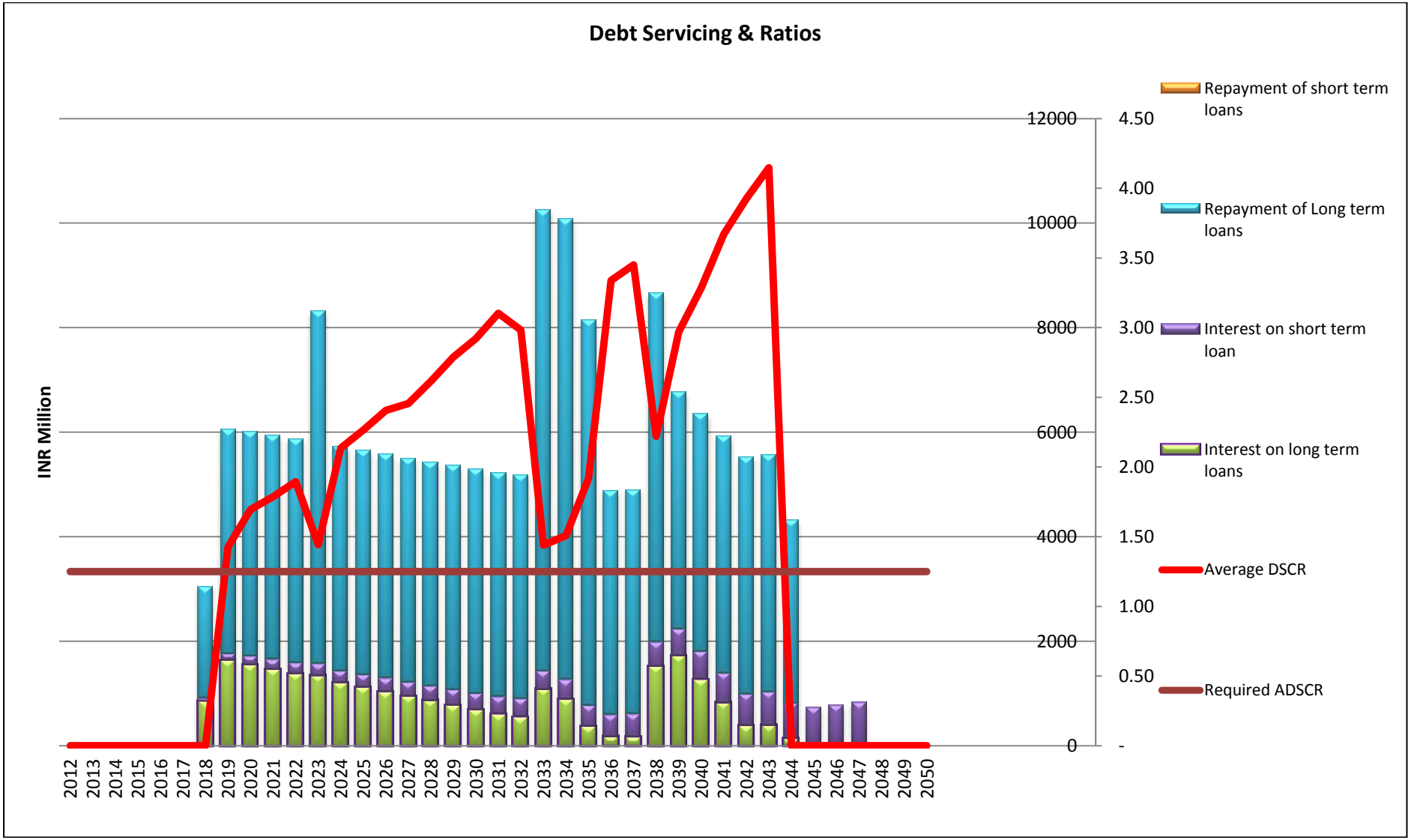
Sr. No.	Description	Amount (INR Million)	Remarks
		NPV@10 %	
A	**Revenue from cess on TOD**		
1	During Construction	5,793	The cess collected during construction phase can be used to fund the equity contribution by the Govt for the project
2	During Operations	**25,087**	The cess collected during the operations period can be utilized for servicing the soft loan
B	Debt Servicing Requirement		
1	Principal Repayment	**19,631**	
2	Interest Payment	**5,106**	
	Total Debt Servicing	**24,737**	
	Surplus after Debt servicing	**350**	**Surplus funds after debt servicing may be distributed among the shareholders.**

Following table provides specific year wise Debt Service coverage and ration calculation.

Table 11-16 : Calculation of Debt Servicing and DSCR

Sr. No.	Description	FY17	FY21	FY22	FY31	FY32	FY36	FY37	FY41	FY46
	Debt Serving									
1	PAT	391	4189	5012	10005	8422	11362	13771	18652	24740
2	Depreciation	5318	5342	5416	4540	4902	4902	3475	2041	2038
3	Interest	902	1589	1566	900	1438	611	1985	986	821
4	Total Cash Available During Loan Tenor	**6611**	**11120**	**11993**	**15446**	**14763**	**16875**	**19231**	**21679**	**27600**
	Total Debt	**3042**	**5869**	**8317**	**5180**	**10254**	**4890**	**8662**	**5522**	**821**
1	Cash Available for Debt Servicing	**6611**	**11120**	**11993**	**15446**	**14763**	**16875**	**19231**	**21679**	**27600**
2	Cash Available Post Debt Service	**3569**	**5251**	**3676**	**10266**	**4508**	**11985**	**10570**	**16157**	**26778**
3	Annual DSCR	2.17	1.89	1.44	2.98	1.44	3.45	2.22	3.93	33.60
4	Minimum DSCR	1.43								
5	Average DSCR	2.96								
6	Required DSCR	1.25								
7	Year of Default	Nil								
8	No. of Distress Years	Nil								
9	Year of First Distress	Nil								

From the above table it prudent that minimum Debt service coverage ratio (DSCR) is 1.43 which is well above the standard requirement of 1.25. Further, the average annual DSCR is also healthy at 2.96 and hence debt servicing requirement can be met comfortably.


Debt Servicing & Ratios
INR Million
12000
10000
8000
6000
4000
2000
0
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
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2050
Repayment of short term loans
Repayment of Long term loans
Interest on short term loan
Interest on long term loans
Average DSCR
Required ADSCR

11.14 Life Cycle Capital Investment Analysis

It is suggested that all the future investment need to be done by the private sector. The total lifecycle cost investment by the government and private sector partner in terms of 2011 price levels is presented below.

Table 11-17 : Project Components – Government vis` a vis` Private Sector

Sr. No	Project Components	Total	Government	Private Sector
		Rs. Million		
1	Land, R&R, Utility shifting & Misc. works	**19,066**	19,066	-
2	Civil works, Alignment and formation	**57,589**	57,589	-
3	Station Building	**23,936**	9,802	14,134
4	E&M Works	**7,455**	4,520	2,935
5	Depot-cum-Workshop	**2,057**	1,087	970
6	Permanent Way	**6,340**	6,340	-
7	Traction & Power Supply incl. OHE, ASS etc.	**7,581**	7,581	-
8	Signalling and Telecom.	**7,553**	-	7,553
9	Automatic fare collection	**799**	-	799
10	Rolling Stock	**17,640**	-	17,640
11	Miscellaneous Items	**1,271**	-	1,271
12	General Charges incl. Design charge	**6,736**	4,471	2,265
13	Contingency	**7,901**	5,523	2,378
14	**Total Base Construction Cost**	**165,925**	**115,979**	**49,946**
15	**Percentage Distribution**	**100%**	**69.90%**	**30.10%**
16	IDC & Margin Money	3,069		3,069
17	Future Capital Investments	13,763		13,763
18	Replacement Cost	13,922		13,922
19	**Total Life Cycle Investment**	**196,679**	**115,979**	**80,700**
20	**Percentage Distribution**	**100%**	**59%**	**41%**

11.15 Scenario Analysis

A comprehensive scenario analysis has been conducted to understand the impact of variation in various revenue and cost elements on the feasibility of the project. Project IRR, Equity IRR and DSCR have been calculated to understand the project feasibility under various scenarios

11.15.1. Defining Scenarios

Following scenarios have been generated in the financial model and IRR's and DSCR have been calculated for each of the scenario. It may be noted that each

scenario is independent in its own and all scenarios are mutually exclusive. This analysis is for comparison of the base case with individual scenarios.

- Scenario 1 – Waiver in central and State taxes on Capital cost
- Scenario 2 – Variation in capital cost by +10% or -10%
- Scenario 3 – Variation in farebox revenue by +10% or -10%
- Scenario 4 – Variation in total project revenue by +10% or -10%
- Scenario 5 – Variation in O&M cost by +10% or -10%
- Scenario 6 – Long term loan rate of interest 10% instead of 2%

11.15.2. Scenario Results

The table below presents the results of running the above scenarios in the financial model.

Table 11-18 : Results of Scenario Analysis

Sr. No.	Scenarios	Project IRR	Equity IRR	Average DSCR	Min. DSCR
I	**Base Case**	**4.25%**	**15.85%**	**2.96**	**1.43**
1	Project Cost				
a	Without Central Taxes	4.90%	16.54%	3.26	1.55
b	Without State & Central Taxes	5.29%	17.01%	3.40	1.64
2	Project Cost				
a	Increase by 10%	3.57%	15.01%	2.73	1.30
b	Decrease by 10%	4.99%	17.36%	3.20	1.55
3	Fare Box Revenue				
a	Increase by 10%	5.06%	16.65%	3.33	1.54
b	Decrease by 10%	3.30%	14.96%	2.58	1.31
4	Project Revenue				
a	Increase by 10%	5.27%	17.01%	3.40	1.62
b	Decrease by 10%	3.06%	14.57%	2.51	1.23
5	O&M Expenditure				
a	Increase by 10%	3.74%	15.34%	2.75	1.35
b	Decrease by 10%	4.72%	16.33%	3.17	1.51
6	Long Term Loan Interest rate@10%	4.65%	12.70%	2.12	0.67

11.16 Recommendations and Way forward

Financial Analysis of DMInfraco and DMRollco have been made in order to ensure that there are no hidden surprises at the time of bidding the project.

It would be prudent for NCRPB to select one PPP structure for all RRTS project and develop a bidding criteria which can stand the test of time as well as variability of various RRTS Project.

It is proposed that DMInfra will cary 10% stake in DMRollco thus 10% stake in DMRollco by DMInfraco assumes great signification since DMInfraco will bid out the project, based on the valuation of equity of DMRollco. This would be by way of positive or negative valuation for nominal 10% of DMRollco share by the Concessionaire who shall have the controlling stake in the DMRollco.

It may be noted that the project have been further stress tested to understand if the project can sustain marked borrowing at 10-12% and the result for project are acceptable.

To move forward on the project, following actions could be taken immediately:

(i) Formulation of DMInfraco with equity share holding with percentage as suggested in the report
(ii) Setting up of DMRollco with minimum capital charges are required in terms of company law
(iii) Commencement of negotiation with financial institution and Government of India for obtaining soft loan.
(iv) Selection of suitable transaction advisory:
    a) Commencement dialogue with Government
    b) Commencement with bidding process
(v) Inviting state governments to obtain necessary equity stake in the Infraco.
(vi) Declaration of Transit Oriented Development zones
(vii) Preparation of Development Plans based on ToD Areas identified by this report within a timeframe say 3 months of release of this report
(viii) Legislation for collection of cess from ToD areas
(ix) Land acquisition where required for the project infrastructure area

12. ECONOMCI EVALUATION OF RRTS

12.1 Approach

Economic viability of the proposed RRTS project has been assessed within the broad framework of "Cost-Benefit Analysis", generally used for appraisal of public investment projects. In economic evaluation, benefits are computed for the economy as a whole rather than for an individual entity who has made the investment. In case of financial analysis the profits become the major factor for evaluation whereas in economic analysis the benefits to the economy are the main criteria for evaluation.

The economic analysis involves comparison of project costs and benefits in economic terms under the "with" and "without" project conditions and determining the Economic Internal Rate of Return (EIRR) of the project using discounted cash flow technique. This shows the return which the society could expect from the proposed investment during the project life, i.e. analysis period. The EIRR is then compared with the accounting rate of return considered as the cut-off point for undertaking the investment by the Government of India and international funding agencies like the World Bank and the Asian Development Bank (ADB).

The main steps followed are:

i) Estimation of capital and maintenance costs at economic prices, along with the capital cost phasing
ii) Estimation of economic benefits
iii) Comparison of annual streams of costs with benefits and estimation of EIRR

The project is further subjected to sensitivity analysis by assessing the effects of adverse changes in the key variables on the base EIRR. This helps to gauge the economic strength of the project to withstand future risks and uncertainties.

12.2 The Improvement

Description of economic benefits and costs of the Delhi –Ghaziabad- Meerut RRT requires the identification of the changes brought out by it in the transport sector of the economy. Most importantly, RRTS contributes to the diversion of a high proportion of current private traffic from road to RRT and serves part of the growing passenger traffic demand in NCR. As a result, there will be a reduction in the number of buses, passenger cars and other vehicles carrying passengers on NCR roads. There will be savings in travel time for passengers traveling by RRT due to higher speed and residual traffic left on road will also be benefited due to reduced congestion. The RRTS will also bring about a reduction in air pollution because of the substitution of electricity for petrol and diesel and enhances safety on the roads. There will also be a reduction in the number of accidents on the roads.

Investment in the RRT could result in the reduction of government investments on road developments and buses as also in the private sector investment on buses, cars and other vehicles carrying passengers. There will be reductions in motor vehicles operation and maintenance charges to both the government and the private sector.

In addition, there will be health and other environmental benefits to the public due to reduced pollution from the transport sector of NCR. Land and house property owners gain from the increased valuation of house property prices due to the RRT.

While some of the above benefits are quantifiable, others are difficult to measure. For the proposed project, benefits from following were assessed:

a) Savings in Fuel Consumption
b) Savings in Vehicle Capital Costs
c) Savings due to reduced Environmental Pollution
d) Savings in Travel Time
e) Savings in Road Construction costs

In addition the items quantified above, the community will be benefited by following items which are difficult to quantify. These are listed below;

- Health Benefits.
- Savings due to fewer accidents
- Savings in vehicular operating costs due to the decongestion effect on residual traffic
- Land price increase

12.3 Project Cost Scheduling

The cost of the proposed RRTS infrastructure project consists of two main components:

- Capital cost of construction of RRTS
- Operation and Maintenance cost

Economic analysis requires the conversion of financial costs into economic costs to take care of distortions in prices due to market imperfections. Taxes and duties are removed from financial prices, as these are not real costs to the economy, but are only transfer payments.

All financial costs have been converted into economic costs, which are net of taxes and duties, by applying the standard conversion factor of 0.9.

12.3.1. Capital Cost and its Phasing

The capital cost of the project in financial terms is estimated at Rs. 16,5924.73 Million (2011 prices). The project cost is to be incurred over four years, with 20% in 2013, 20 % in 2014, 30% in 2015 and remaining 30% in 2016. The facilities will be operational from 2016. The economic cost of the project works out by applying the conversion factor of 0.9 to financial costs.

12.3.2. Operation and Maintenance Cost

The operation and maintenance (O&M) cost involves energy cost, staff cost and other operation and maintenance of running RRTS and related facilities. The cost of operation and maintenance is estimated and described in Operation and Maintenance chapter.

The operation and maintenance cost is also converted into economic costs by applying a factor of 0.90. The operation and maintenance cost in financial terms is Rs

5,909 Million per year. The corresponding cost in economic terms is Rs. 5,318.10 Million per year.

12.4 Project Benefits

The commissioning of the proposed RRTS project is expected to result in both direct and indirect benefits to the users. The present analysis covers quantification of direct benefits in terms of savings in time, VOC/fuel, capital cost of cars, highway construction. Benefits due to improved environmental conditions are also quantified using rapid techniques.

12.4.1. Time Savings

In order to work out time savings, the speeds for different vehicles have been calculated from surveys. The RRTS speeds were determined from simulation done as part of operation plan. The time savings have been worked out as the difference of travel time under "with and "without" project situations. The savings of travel time of passengers traveling by the RRTS instead of by road are calculated as the product of the number of passengers traveled daily and the time saved on the average passenger trip lead on the corridor.

The average Value of Time per person is arrived based on traffic surveys conducted for project. The average VOT rates adopted are Rs. 82 per hour. Passenger time saving per annum for RRTS is then calculated as the product of daily passengers carried, time saved on average lead on an annual basis and the value of time of RRTS passengers. Benefits to residual vehicles are not considered in present analysis. The total time savings per year are presented in Table 12-1 below.

Table 12-1 : Estimated Savings in Passenger Time Cost

Sr. No.	Year	Time Savings (Rs. Million/Year)
1	2016	16,661.3
2	2021	21,338.1
3	2031	37,999.4
4	2041	46,443.8

12.4.2. Fuel Cost Savings

There are savings in fuel consumption due to the diversion of a part of the road traffic to RRTS and reduced congestion to vehicles still operating on the roads. Fuel saved due to traffic diverted to the RRTS is estimated given the estimates of diverted traffic and the distance travelled and fuel consumption norms of different vehicles. The total fuel savings based on 2011 price levels is presented below in table 12-2.

Table 12-2 : Estimated Fuel Savings Cost

Sr. No.	Description	Units	2016	2021	2031	2041
1	Estimated fuel savings/year	Thousand liter	99,220	127,071	156,663	191,477
2	Cost of fuel saved/ year	Rs. Million	5,920	7,430	9,160	11,420

12.4.3. Savings in Road Construction Cost

Due to the lesser number of vehicles on road due to RRTS, lesser road capacity will be required. This will results in savings of highway construction cost. To estimate savings, total additional highway lanes required in "without RRTS situation" were calculated and multiplied with average construction cost of Rs 30 crore/km for 2+2 lane express highway for 90 km length. The land acquisition cost was estimated by assuming 60 m ROW requirement for 90 km stretch. The savings are as under in table 12-3.

Table 12-3 : Estimated Savings in Cost of Road Construction

Sr. No.	Year	Additional Lane Required	Construction Cost	Land Acquisition Cost	Remarks
			Rs. Million	Rs. Million	
1	2016	4	27,000	32,400	
2	2021	8	27,000		Additional cost
	Total		**54,000**	**32,400**	

12.4.4. Environmental Benefits

Fewer vehicles and the decongestion for the residual traffic on influence area roads due to RRTS could lead to reduced air pollution. An estimate of the pollution reduction by a vehicle in this context could be obtained by multiplying the distance saved by the relevant emission coefficient for different pollutants for each category of vehicle. The emission coefficients for different vehicles are given in the table 12-4. Estimates of reduction in distance traveled every day due to the lesser vehicles on the road is estimated by assuming average vehicle travel of 60 km for cars, 40 kms for 2 wheelers and 200 km for buses. The environmental benefits for different roads are also presented in the table 12-4.

Table 12-4 : Pollutant by Vehicle Type

Pollutant	Car	2wheel	Bus
PM	0.03	0.075	0.05
NOX	0.2	0.3	0.87
HC	0.075	0.7	2.75
CO	0.08	2.2	0.66

The monetary value of these pollution loads are estimated using the estimates of prices of pollutants made in some recent studies in India.

The estimated savings are given in table 12-5.

Table 12-5 : Estimated Savings in Pollutants

Sr. No.	Year	Savings (Rs. Million/Year)
1	2016	2,408
2	2021	3,084
3	2031	3,803
4	2041	4,648

12.4.5. Vehicle Capital Cost Savings

The number of vehicles going off the road due to the introduction of RRTS was estimated by determining the shift of private vehicle passengers and bus passengers. Based on average occupancy of various vehicle types, passenger data was converted into vehicles for analysis purpose. This data was projected as per the transport demand forecasts conducted for the project. The total capital cost saving due to fewer vehicles on the road is estimated and presented in Table 12-6 below:

Table 12-6 : Estimated Vehicle Capital Cost Savings

Sr. No.	Year	Savings (Rs. Million/Year)
1	2016	36,200
2	2021	10,160
3	2031	10,800
4	2041	12,700

12.5 Economic Internal Rate of Return

The benefits of fuel cost savings, time savings due to increased speed, construction cost saving of roads, saving of capital cost of vehicles and environmental benefits are added together to get the total savings. The net cash flow statements are presented in table 12-7. The rate of return considered desirable for the transport infrastructure project in India is 12 percent. As EIRR of proposed RRTS facility is 24.10 %, which is above 12 percent cut-off rate, the project is considered economically viable.

Table 12-7 : Net Cash Flow Statement (in Rs. Million)

Year	Costs		Benefits						Net Benefits
	Capital Costs	Maintenance	Fuel Cost Savings	Time Savings	Vehicle Capital cost savings	Environmental Benefits	Highway cost savings	Total	Net Benefit
2013	29,866	5,318							(35,185)
2014	44,800	5,318							(50,118)
2015	44,800	5,318							(50,118)
2016	29,866	5,318	5,920	16,661	36,204	2,408	59,535	20,729	85,544
2017		5,318	6,195	17,435	-	2,520	135	26,286	20,968
2018		5,318	6,483	18,246	-	2,637	135	27,501	22,183
2019		5,318	6,784	19,093	-	2,760	135	28,772	23,454
2020		5,318	7,099	19,980	-	2,888	135	30,103	24,785
2021		5,318	7,429	21,338	10,163	3,084	27,675	69,689	64,371
2022		5,318	7,586	21,790	-	3,150	270	32,796	27,477
2023		5,318	7,747	22,251	-	3,216	270	33,484	28,166
2024		5,318	7,911	22,721	-	3,284	270	34,186	28,868
2025		5,318	8,078	23,202	-	3,354	270	34,904	29,586
2026		5,318	8,249	23,693	-	3,425	1,350	36,717	31,398
2027		5,318	8,423	24,194	-	3,497	270	36,385	31,067
2028		5,318	8,602	24,706	-	3,571	270	37,149	31,831
2029		5,318	8,784	25,229	-	3,647	270	37,929	32,611
2030		5,318	8,969	25,762	-	3,724	270	38,726	33,408
2031		5,318	9,159	37,999	10,798	3,803	1,350	63,109	57,791
2032		5,318	9,364	38,849	-	3,888	270	52,370	47,052
2033		5,318	9,573	39,717	-	3,975	270	53,534	48,216
2034		5,318	9,787	40,604	-	4,063	270	54,725	49,406
2035		5,318	10,006	41,511	-	4,154	270	55,941	50,623
2036		5,318	10,229	42,439	-	4,247	1,350	58,265	52,947
2037		5,318	10,458	43,387	-	4,342	270	58,457	53,139
2038		5,318	10,692	44,357	-	4,439	270	59,757	54,439
2039		5,318	10,930	45,348	-	4,538	270	61,087	55,769
2040		5,318	11,175	46,361	-	4,640	270	62,446	57,128
2041		5,318	11,424	46,444	12,703	4,648	1,350	76,569	71,251
								Economic Internal Rate of Return (EIRR)	**24.10%**
								Net Present Value (In Million Rupees)	**159,370**

12.6 Sensitivity Analysis

The robustness of the project's viability is further demonstrated by the sensitivity analysis. Because of the uncertainties pertaining to traffic forecasts and critical parameters relating to cost and benefits, a sensitivity analysis was carried out to test the economic strength of the project. The variations in the following parameters have been examined, considering them to be on the conservative side:

i) Increase in cost by 10 percent
ii) Decrease in benefits by 10 percent
iii) Increase in cost by 10 percent and decrease in benefits by 10 percent

The results of the sensitivity analysis are presented below**.**

Table 12-8 : Sensitivity Analysis Results

Case	Economic Internal Rate of Return	Net Present Value (Million Rupees)
10% increase in costs	21.99%	147,546
10% Decrease in benefits	21.23%	126,627
10% increase in costs and 10% decrease in benefits	19.36%	114,803

It may be noted that project perform reasonably well even in worst conditions.