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LIST OF ABBREVIATION

AFTC	Audio Frequency Track Circuits
ARSD College	Atma Ram Sanatan Dharm College, Delhi
ATO	Automatic Train Operation
ATP	Automatic Train Protection
ATS	Automatic Train Supervision
BTK	Bhiwadi- Tapookara- Khushkhera Complex
CAR	Corridor Alignment Report
CATC	Continuous Automatic Train Control
CBD	Central Business District
CBTC	Communication Based Train Control
CENELAC SIL-4	European Standard – Safety Integrity level four
CNCR	Central National Capital Region
CRC	Consultancy Review Committee
DAMEL	Delhi Airport Metro Express Line
DFC	Dedicated Freight Corridor
DGRA	Delhi-Gurgaon-Rewari-Alwar
DIMTS	Delhi Integrated Multi Model Transport Services
DMIC	Delhi Mumbai Industrial Corridor
DMRC	Delhi Metro Rail Corporation Limited
DPR	Detailed Project Report
DTC	Delhi Transport Corporation
DTS	Data Transmission System
EMU	Electro-motive Units
HVAC	Heating, Ventilation and Air Conditioning
IR	Indian Railways
ISBT	Inter State Bus Terminus
KMP	Kundli-Manesar-Palwal
LMV	Light Motor Vehicle
MBIR	Manesar-Bawal Investment Region
MOU	Memorandum of Understanding

MOUD	Ministry of Urban Development
MRTS	Mass Rapid Transit System
NATM	New Austrian Tunnelling Method
NCR	National Capital Region
NCRPB	National Capital Region Planning Board
NCTD	National Capital Territory Delhi
NDLS	New Delhi Railway Station
NH	National Highway
NZM	Nizamuddin
OCC	Operations Control Centre
OFC	Optical Fibre Cable
PHPDT	Peak Hour Peak Direction Trips
RDSO	Research Design and Standards Organisation
Rajiv Chowk (G)	Rajiv Chowk (Gurgaon)
RFID	Radio Frequency Identification Device
ROW	Right of Way
RRTS	Regional Rapid Transit System
SDH	Synchronous Digital Hierarchy
SEZ	Special Economic Zones
SH	State Highway
SNB	Shahjahanpur – Neemrana – Behror – Complex
TO	Train Operator
TOD	Transit Oriented Development
TSS	Traction Sub Station
UMTC	Urban Mass Transit Company Limited

1. Introduction

1.1. Study Background

The National Capital Region Planning Board (NCRPB), in order to enhance the connectivity within the National Capital Region, has proposed to connect the Urban, industrial (SEZs/industrial parks), regional and sub-regional centers through a Regional Rapid Transit System (RRTS). The Integrated Transportation Plan 2032 has identified eight rail based rapid transit corridors to enhance the efficacy of the transportation system in the NCR (Figure 1-1) in addition to providing other facilities including road network enhancements.

Figure 1-1 National Capital Region

The eight identified RRTS corridors are:

1. Delhi – Gurgaon – Rewari – Alwar [DGRA - Project Corridor]
2. Delhi – Ghaziabad – Meerut
3. Delhi – Sonipat – Panipat
4. Delhi – Faridabad – Ballabhgarh – Palwal
5. Delhi – Bahadurgarh – Rohtak
6. Delhi – Shahadra – Baraut
7. Ghaziabad – Khurja
8. Ghaziabad – Hapur

The proposed RRTS corridors are shown in Figure 1-2

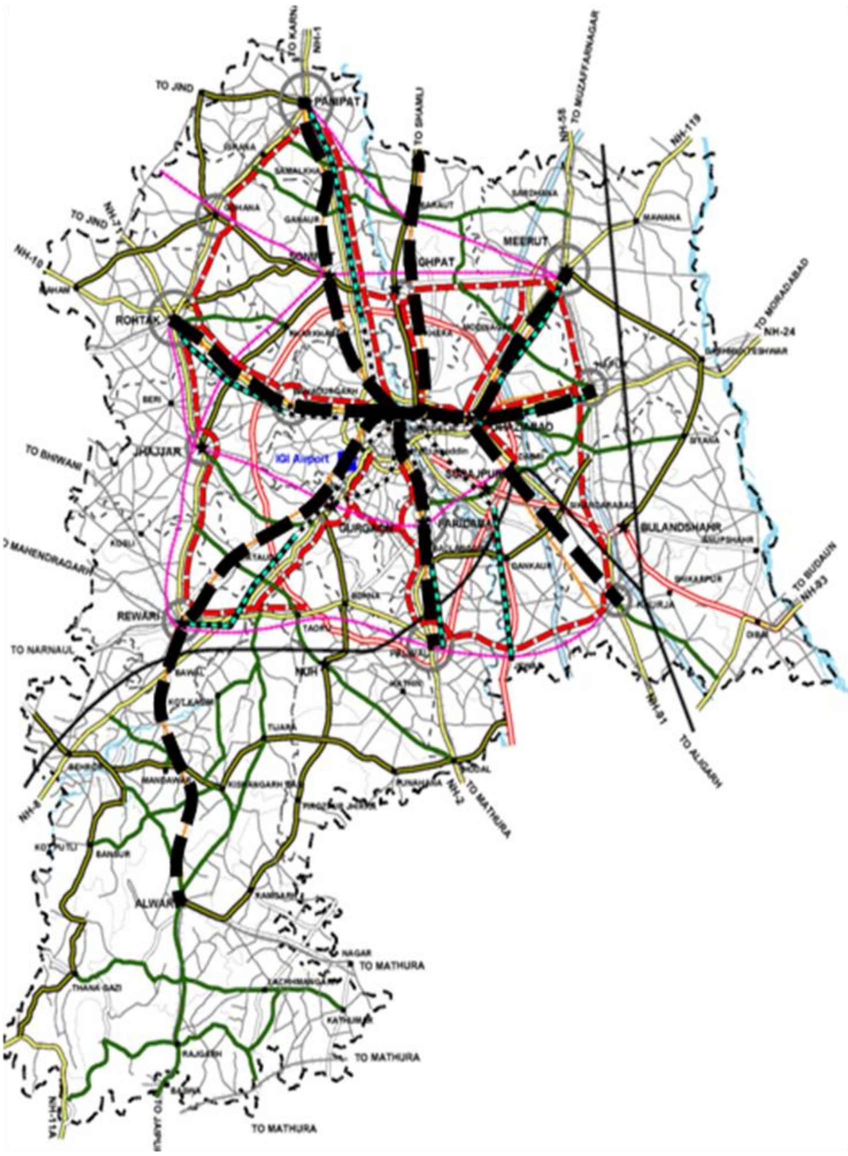


Figure 1-2 National Capital Region and Proposed RRTS corridors

The proposed corridors radiate from National Capital Territory Delhi (NCTD) across the NCR area and terminate at Rest of NCR (RNCR) towns which are the exit nodes of NCR. The RRTS network thus defined is expected to provide a fast transportation system for intra regional movement of passengers.

UMTC has been mandated to conduct the feasibility study and to prepare the DPR for the Delhi-Gurgaon-Rewari-Alwar (DGRA) Corridor. As part of study, the objective of this report is to assess the technical and financial feasibility of the approved RRTS corridor connecting Delhi to Alwar via Gurgaon and Rewari.

The study area considered is shown in **Figure 1-3**.

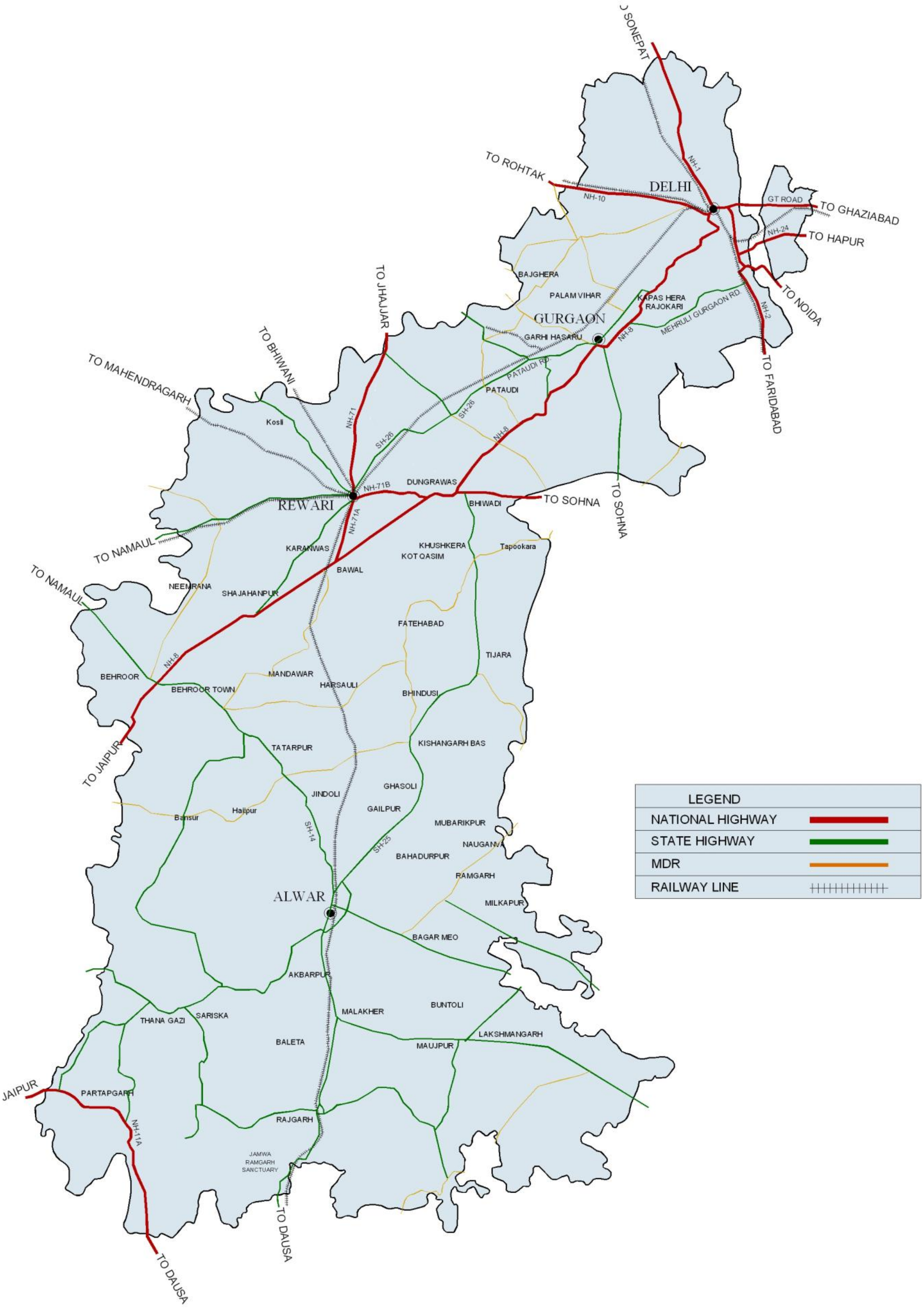


Figure 1-3 Study Area Map

1.2. Progress so Far

As per the reporting requirement of the consultancy services contract, the consultant has submitted the following five reports so far

(a) Inception Report on 03.05.2010

(b) Existing Condition Analysis Report on 23.07.2010

(c) Travel Demand Forecast Report on 18.10 2010

(d) Addendum to Travel Demand Forecast Report on 27.12.2010

(e) Corridor Alignment Report on 30.12.2010

UMTC submitted Corridor Alignment Report after complete discussions with the Governments of three states viz NCT Delhi, Haryana and Rajasthan and after including the suggestions made by the CRC members and those that came out as a result of the discussions with the State Government officers. The Consultants gave a presentation on the Corridor Alignment Report on the 17.03.11 wherein the proposed Alignment was accepted by the CRC. It was approved by the task force chaired by the Secretary, MoUD, in the meeting held on 29th June 2011.

This "Feasibility Report" has been prepared based on the approved RRTS alignment, and the traffic demand on it, brain storming sessions have been conducted for the finalization of systems specifications, it includes the cost of the fixed as well as rolling infrastructure, the revenue generation, and overall technical and financial feasibility of the project.

1.3. Scope of the Report

This report describes the various constituents of the Delhi-Gurgaon-Rewari-Alwar RRTS system. In order to achieve the RRTS objectives, the technical specifications have been discussed and proposed in coherence with the operational requirement to serve the traffic needs in the corridor. The block costing has been carried out and revenue generation and funding options have been identified. An attempt has been made to assess the level of economic and financial feasibility of the project.

1.4. Report Structure

The report contains the following chapters

Chapter 1. Introduction:

This chapter gives the background of RRTS and the scope of the report

Chapter 2. Travel Demand Forecast

This chapter summarises the findings of the traffic study and states the travel demand on the proposed alignment for the various horizon years including the various forecast travel characteristics

Chapter 3. System Selection

The available systems have been discussed in brief, and the most suitable system viz. Telecommunication and Signalling system, the Rolling Stock specifications, Traction, Civil infrastructure requirement and automatic fare collection etc. have been proposed

Chapter 4. Civil Engineering

This chapter details out the civil engineering aspects of the project including the elevated, at-grade and underground structures and the geometric design norms that have been adopted for this project including the land aspects

Chapter 5. Train Operations

The various operational aspects of the RRTS have been explained in this chapter. It also includes the rolling stock requirement for various horizon years, the train running frequencies in peak and non-peak periods of the day, and the train time table

Chapter 6. Signalling, Telecommunication and Fare Collection Systems

The various signalling and telecommunication systems available have been briefly discussed and the systems proposed have been elaborated in this chapter. Automatic Fare collection system and its monitoring details has also been described

Chapter 7. **Rolling Stock**

The various features of the rolling stock including axle loads, capacity etc. are described in this chapter

Chapter 8. **Power Supply and Traction**

The power requirement for traction and auxiliary services has been calculated and the sources have been identified in this chapter. It also highlights the various power saving measures that will be adopted in the system.

Chapter 9. **Ventilation and Air Conditioning System**

This chapter gives details of the HVAC systems and the standards to be adopted for the underground portion of the RRTS

Chapter 10. **Depots**

All the fixed and rolling stock infrastructure of the RRTS needs to be maintained in order to sustain the operational efficiency of the system. The detailed requirement and plan for the maintenance of the rolling stock has been explained in this chapter.

Chapter 11. **Cost Estimates**

This chapter gives the block cost estimates of the RRTS including the cost of all sub systems and the related charges and contingencies.

Chapter 12. **Financial Analysis**

This chapter analyses the various costs and revenue streams of the project, it attempts to assess the financial viability of the project and the funding options for the project.

Chapter 13. Economic Analysis

This chapter analyses the various costs and benefits from the project, it tries to assess the economic and social viability of the project.

Chapter 14. Way Forward

This chapter lists out the future line of action by the consultant on the project and the assistance required from the client.

2. Travel Demand Forecast

2.1. Introduction

The traffic studies for identifying the recommended alignment and forecasting the future traffic for the alignment was carried out based on primary and secondary data collection. The transport planning process primarily consists of development of a set of formulae / equations which are referred as models, enabling forecast of future travel demand and traffic characteristics. It is not just one model but a series of interlinked models of varying levels of complexity dealing with different facets of travel demand. Planning variables at zonal level, such as population, employment, land use and transit oriented development have been made use of in the transport demand analysis.

Identification of the final RRTS DGRA alignment has been a meticulous exercise as it aimed to provide connectivity to the maximum part of the NCT and was a process of identifying the highest mobility corridor, keeping in view the future developments proposed in the region. Several options for alignment were explored before selecting the most suitable alignment for the RRTS which was:-

Mainline: ISBT Kashmere Gate - New Delhi RS – Sarai Kale Khan (Nizammuddin) – INA – Dhaula Kuan – Mahipalpur – Cyber City – Rajiv Chowk (G) – Manesar – Panchgaon – Dharuhera – BTK – MBIR – Rewari – Bawal – SNB – Khairthal – Alwar.

Spur Line: Cyber City – Udyog Vihar – Bijwasan – Dwarka Sector 21

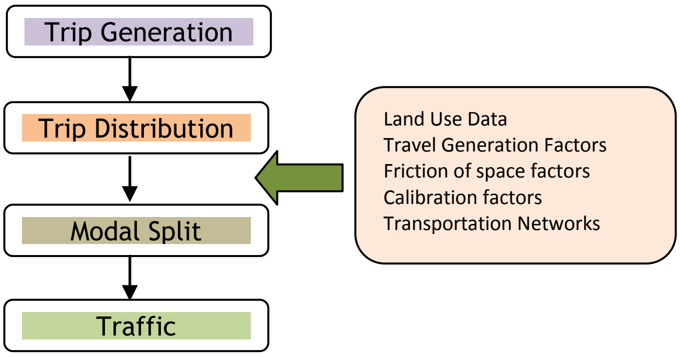
However, as per the decision taken in the meeting held on 30/08/2011 (Ministry of Urban Development letter no.K-14011/11/2010-Metro dated 19.09.2011) the Spurline connecting Dwarka Sector-21 to IFFCO Chowk RRTS Station has been dropped from the alignment proposal, instead a station has been proposed at IFFCO Chowk in order to integrate with the proposed extension of the Delhi Airport Metro Express line (DAMEL) at NH-8 near IFFCO Chowk. Hence the finalised Alignment consist the following stations:-

ISBT Kashmere Gate - New Delhi RS – Sarai Kale Khan (Nizammuddin) – INA – Dhaula Kuan – Mahipalpur – Cyber City – IFFCO Chowk - Rajiv Chowk (G) – Manesar – Panchgaon – Dharuhera – BTK – MBIR – Rewari – Bawal – SNB – Khairthal – Alwar.

The traffic forecast has been carried out for this alignment taking into account the influence on RRTS traffic due to the connectivity of the zones connected by the DAMEL and the DMRC Gurgaon Line. The details of the travel demand and traffic characteristics have been provided in the sub sections below.

2.2. Estimation Procedure

For traffic estimation, the general four-step modelling framework was adopted. The model was calibrated for the peak hours of the day. Model focuses on the morning and evening peak periods because these conditions include the most important recurrent congestion period and tend to guide transportation system design.



The four stages of the transportation model are

- Trip Generation – estimating number of origins and destinations for each zone.
- Trip Distribution – attaching the origins and destinations for each trip to complete trips.
- Mode Choice – determining the mode of travel for each trip (car, auto rickshaws, transit).
- Assignment – establishing routes and transit paths.

Basic inputs were (a) Passenger origin-destination, (b) Trip end models, (c) Properly calibrated integrated transport network which was developed from (i) Traffic zone system, (ii) Road, Rail, Metro network, (iii) Future land use data and (iv) latest calibrated values of traffic sub models for which sample field surveys were conducted.

2.3. Broad Model Overview

The Delhi- Gurgaon Model was developed about 3 years ago and included all of the Delhi Area, the Noida Area and the Gurgaon Area. The model included

- Zones – 404 (including External Zones)
- Bus Routes-681
- Shared auto routes-25
- Links (roads)-3700
- Nodes (junctions)-2753
- Road length – 2220 km
- Metro routes- 5

The model was calibrated for the peak hour and included 4 modes – Cars/Taxi, Auto rickshaws, Two Wheelers and Public Transport.

Planning Period: Year 2010 is considered as the base year and 2016, 2021, 2031 and 2041 have been set as the horizon years

Since the RRTS is a mode of transport that is not in use in India, modelling this mode by a direct assignment process computing minimum cost trips may not be the appropriate method. We have hence used a process called "Direct Utility Assessment".

The estimation of trips on the RRTS is via a Logit model separately calibrated based on opinion surveys. The Trip Matrices generated by the 4 stage modelling have been used to establish the total candidate traffic of the RRTS alignment. The diversion of these trips using the Logit model has been carried out to establish the RRTS trips. This exercise has been carried out for all options of the RRTS route plans.

2.4. Observed Model Validation

Assignment is carried out in two stages with the assignment of Transit trips following the Highway Assignment. The transit assignment is the assignment of commuters on a Public Transit Network which comprises of all public transport modes which are linked on to the zonal system via feeder links. Traffic and public transport flows cutting screen lines were checked with ground counts. The screen line validation results are presented in Table 2-1 and Table 2-2.

Table 2-1: Screen line validation – Private vehicles

Mode	Direction 1			Direction 2		
	Assigned	Observed	%Difference	Assigned	Observed	% Difference
Screen line 1						
Two wheeler	5464	4856	-13%	1516	1340	-13%
Car/ Taxi	8788	9652	9%	7437	7673	3%
Auto rickshaw	51	54	6%	66	59	-13%
Screen line 2						
Two Wheeler	45	44	-2%	84	79	-6%
Car/Taxi	42	40	-4%	48	48	-1%
Auto rickshaw	5	5	3%	7	7	6%
Screen line 3						
Two Wheeler	71	72	1%	65	71	8%
Car/Taxi	84	94	11%	78	74	-5%
Auto rickshaw	16	15	-7%	6	6	0%
Screen line 4						
Two wheeler	151	166	9%	125	128	2%
Car	363	323	-12%	224	243	8%
Auto rickshaw	22	24	10%	33	41	20%
Screen line 5						
Two Wheeler	117	134	12%	185	216	15%
Car	278	277	0%	327	365	10%
Auto rickshaw	68	61	-12%	68	63	-7%
Screen line 6						
Two wheeler	108	112	4%	88	97	9%
Car	161	158	-2%	115	109	-6%
Auto rickshaw	17	16	-3%	9	10	10%

(Note: Numbers are in PCU's) (Direction 1: Towards Alwar, Direction 2: Towards Delhi)

Table 2-2: Screen line validation - Public transport (BUS)

Mode	Direction 1			Direction 2		
	Assigned	Observed	% Difference	Assigned	Observed	% Difference
Screen line 1						
Public transport	22780	25914	14%	23205	24482	6%
Screen line 2						
Public transport	260	245	-6%	345	321	-7%
Screen line 3						
Public transport	190	176	-7%	75	81	8%
Screen line 4						
Public transport	1530	1345	-12%	1615	1521	-6%
Screen line 5						
Public transport	845	754	-11%	1850	2015	9%
Screen line 6						
Public transport	1170	1288	10%	2495	2611	5%

(Direction 1: Towards Alwar, Direction 2: Towards Delhi)

2.4.1 Logit Models

As discussed earlier, while the 4 stage model helps us in estimating forecast mode share and candidate trips on the RRTS, the traffic demand on the RRTS itself is derived through a separately calibrated diversion functions (The logit model). There are two approaches to estimate the demand for new services. One is to use revealed preference technique, through the Urban Travel Demand Model (CUBE model), to estimate the ridership. The second approach is to use stated preference to describe the choice between the new alternative and the existing alternative. Using assignment to establish ridership based on costs may not be appropriate as the RRTS characteristics are different from any known mode in the region.

Stated preference surveys were carried out for various users such as Car, Two wheelers, Auto rickshaw, Rail and Bus at various locations in the RRTS influence area covering a total of 1600 samples. Mode -wise logit models were developed using the results of this survey. In this study, the Utility Assessment (UA) model suggested in the "Guide to Forecasting Travel Demand with Direct Utility Assessment, US Department of Transportation" has been adopted.

The Survey design is presented in Table 2-3.

Table 2-3: WTS Survey Design-SAMPLE

Scenarios/ Situations	Rail Fare (Rs.)	Waiting time (in Minutes)	Travel time reduction	Comfort	Availability of feeder service	Response				
1	1.5 X Metro fare	15	0%	Low	Yes	1	2	3	4	5
2	1.5 X Metro fare	5	25%	High	Yes	1	2	3	4	5
3	0.5 X Metro fare	15	25%	Low	No	1	2	3	4	5
4	1.0 X Metro fare	15	0%	High	No	1	2	3	4	5
5	1.0 X Metro fare	5	25%	Low	No	1	2	3	4	5
6	1.0 X Metro fare	5	25%	High	No	1	2	3	4	5

Note1: Response scale, 1- very unlikely, 2- unlikely, 3- neutral, 4- likely and 5- very likely.

(Rail fare here corresponds to equivalent metro fare)

Linear regression models have been developed using all the above parameters and found that the four variables namely fare, comfort, waiting time and availability of feeder service are significant. The dependent variable i.e. the response, is scaled on a 1

- 5 “likelihood of use” scale with 5 corresponding to the ‘most likely’ selection of the proposed facility and 1 corresponding to being ‘most unlikely’ to choose the facility.

The general form of response model used is:

R = k + a1 * rail fare + a2 * waiting time + a3 * Comfort + a4 * availability of feeder service

Where,

R’ = Response on 1-5 scale,

k, a1, a2, a3 and a4 are coefficients

The notations of variables used in the model development are presented in Table 2-4.

Table 2-4: Notations used in Developing Logit Models

Variable	Values	Notations
Comfort	Low	0
	High	1
Frequency (headway in min.)	5	5
	15	15
Availability of feeder service	Yes	1
	No	0

Mode-wise models were developed for two wheelers, Car, Auto rickshaw, Bus and Rail separately based on the distance of travel. In the model, K- is the constant term and the other terms are X1 – Rail fare, X2 – Waiting time in minutes, X3 – comfort and X4 – Availability of feeder service respectively.

2.4.2 Methodology for calculating candidate trips and diversion

The study area has been divided into proximity zones and influence zones. Within Delhi and Gurgaon areas, zones less than 5 km radius and for the remaining study area zones less than 10 km radius from proposed RRTS stations are considered as proximity zones. The zones beyond and at the starting and at the end point of the alignment corridor are considered as influence zones. The area covered by proximity zones and the influence zones is considered as influence region. The peak hour trips bound between zones identified in the influence region is estimated as candidate trips for that particular alignment. From the response, the probability of shifting to the proposed RRTS from the candidate trips is determined from the following equation:

$$P(m) = \frac{1}{1 + e^{-(R-3)}}$$

Where, P (m) – Probability of using RRTS and R - Response or the Utility function

From the above equation the probability of shift from other modes to the RRTS is estimated.

Different alignments have been tested in the study area and the respective candidate trips and diverted trips are estimated using the logit equations developed for Two wheeler, Car, Auto rickshaw, Bus and Rail separately.

2.4.3 Optimistic and Pessimistic scenario Models

Logit models were built for optimistic and pessimistic scenarios separately for all the modes as well. The optimistic scenario shifts a "likely" response to a "most likely" while the pessimistic scenario shifts the scale backwards.

2.4.4 Transit oriented development

At each proposed station the potential for development has been carried out and according to the type of development i.e., above station (Transit node development) and land adjacent to station (Transit oriented development), the total foot falls per day were calculated. The trips generated due to this have been added to the trips generated in the zone, and the new trip ends so derived have been redistributed in the model to take in to account the impact of TOD.

2.5. Results

The alignment is shown in **Figure 2-1**. The ridership results are presented in the following sub sections.

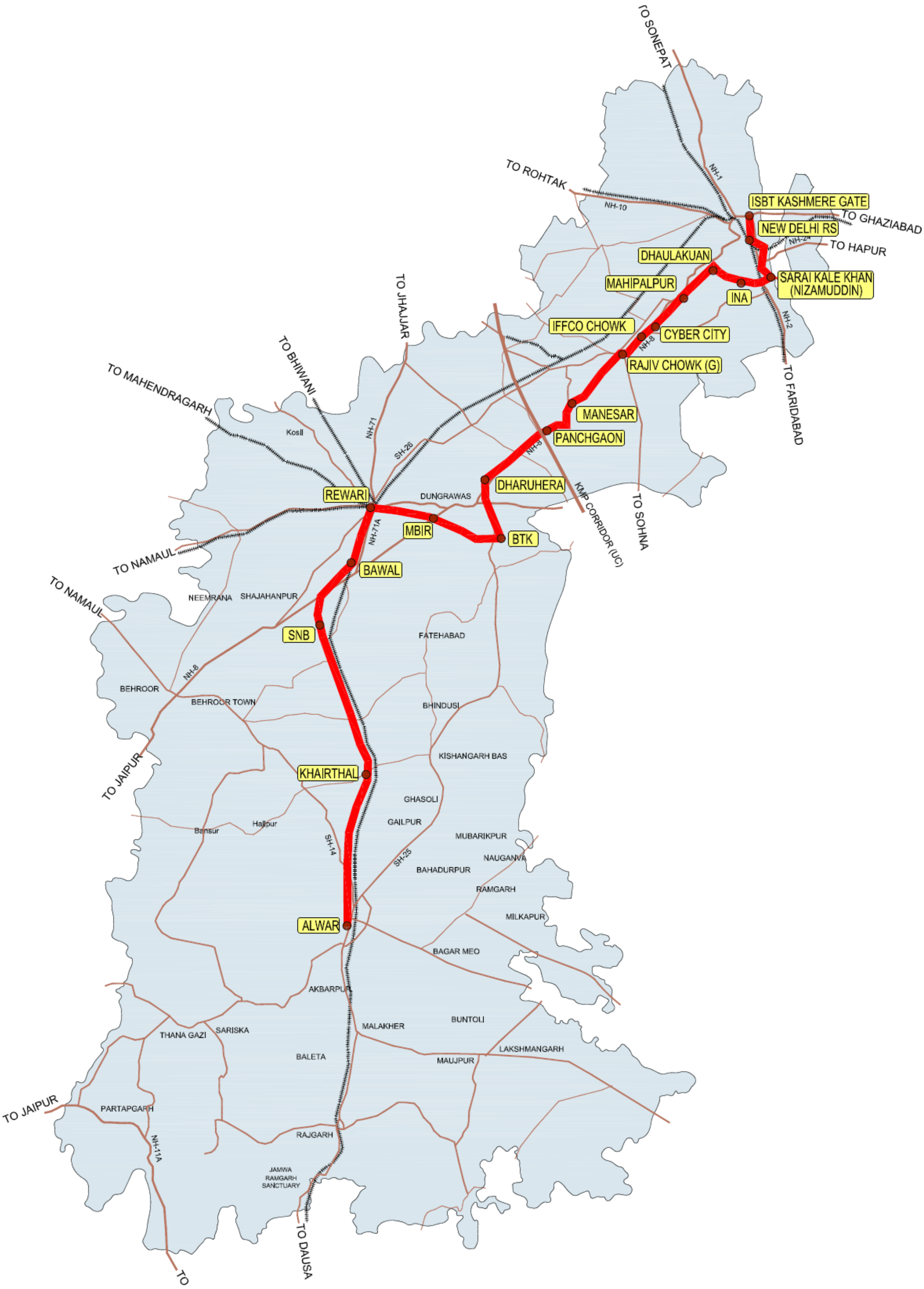


Figure 2-1 – Final alignment

The peak hour candidate trips and diverted trips for 2016, 2021, 2031 and 2041 with TOD are presented in Table 2-5.

Table 2-5: Peak Hour Candidate trips, diverted trips

Mode	Peak Hour Candidate trips	Peak Hour Diverted Trips
2016	979738	69920
2021	1247178	91321
2031	1515061	125593
2041	1798448	151135

2.5.1 Station wise Boarding and Alighting

The daily ridership on the proposed corridor will have an important impact on the feasibility of the project since the revenue generation will depend mostly on the number of people using the facility; this has been forecast by detailed model development and calibration. The daily boarding and alighting at each station is considered to be equal.

The daily boarding-alighting on RRTS for the various horizon years are given in Table 2-6.

Table 2-6: Daily Boarding/Alighting for various stations in RRTS

S.No	Station Name	2016	2021	2031	2041
1	ISBT Kashmere Gate	20390	24540	33095	44340
2	New Delhi RS	26030	32855	42495	54280
3	Sarai Kale Khan (Nizamuddin)	38000	44520	66395	84950
4	INA	24955	31275	47545	55515
5	Dhaulakuan	6000	9270	10140	11565
6	Mahipalpur	66035	87320	131110	145720
7	Cyber City	58210	83760	114145	125675
8	IFFCO Chowk	44760	44655	57535	67105
9	Rajiv Chowk (G)	25285	47105	57035	67145
10	Manesar	46765	61085	87410	96520
11	Panchgaon	24785	34290	38715	44440
12	Dharuhera	29375	33995	40680	45000
13	BTK	59395	76510	93535	115185
14	MBIR	24625	28865	34960	48050
15	Rewari	68000	99795	140735	161165
16	Bawal	62980	82240	135835	167035
17	SNB	38805	46915	61205	93305
18	Khairthal	18615	23155	32150	39285
19	Alwar	15320	20340	30690	44380
	Total	698330	912490	1255410	1510660

2.5.2 Sectional Loads

The peak sectional loads / Peak Hour Peak Direction Trips (PHPDT) are considered for the planning of the train operations, the PHPDT on the final RRTS alignment for the 4 horizon years have been plotted in the graph below.

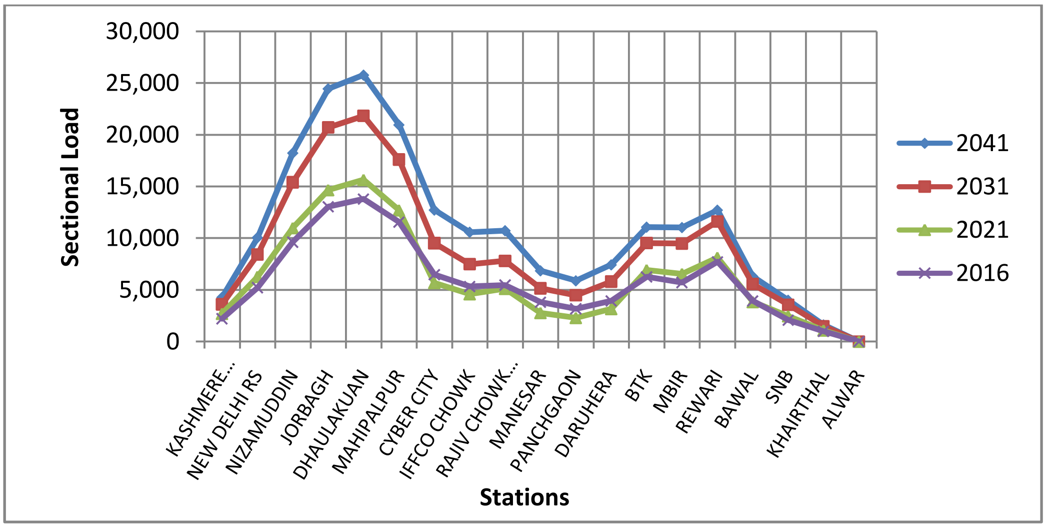


Figure 2-2 – Peak Sectional Loads (ISBT Kashmere Gate to Alwar)

The PHPDT in the direction from ISBT Kashmere Gate to Alwar is 25775 per hour in 2041. It can seen that there is decline in sectional loads after Rajiv Chowk (Gurgaon) in 2016, 2021, however there is an increase in these loads in the year 2031 and 2041 which is mainly due to the increased development in the areas of Dharuhera, BTK, Bawal and SNB.

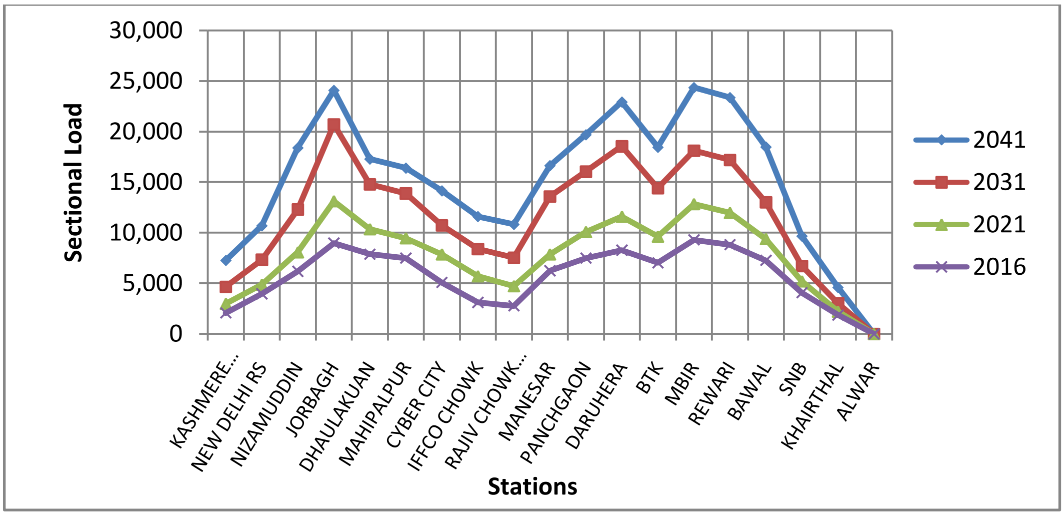


Figure 2-3 – Peak Sectional Loads (Alwar to ISBT Kashmere Gate)

The sectional loads in the direction from Alwar to ISBT Kashmere Gate are distributed along the route; however the PHPDT in this direction is less than 25000. The PHPDT will decide the number of trains in operation for the peak hour.

2.5.3 Hourly Distribution

The traffic on the RRTS will not be equally distributed throughout the day. The peak on various sections along the length of the alignment will be varying, however to analyse the peak traffic on the RRTS alignment the hourly variation on the RRTS from ISBT Kashmere Gate to Alwar is provided in the Figure No.2-4

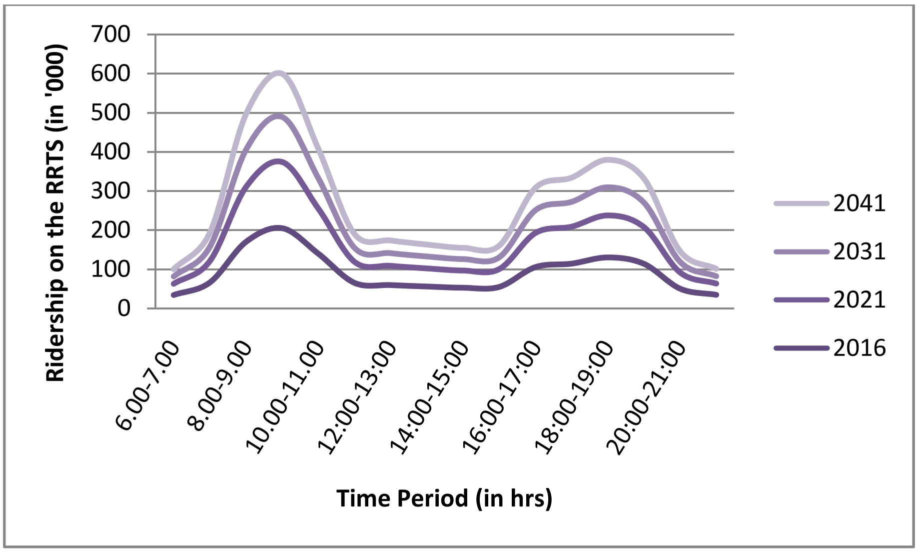


Figure 2-4 – Hourly Variation (ISBT Kashmere Gate to Alwar)

It can be seen that the peak traffic on the RRTS will be from 8 to 10 AM in the morning in this direction. The hourly variation in the direction from Alwar to ISBT Kashmere Gate is provided in the Figure 2-5

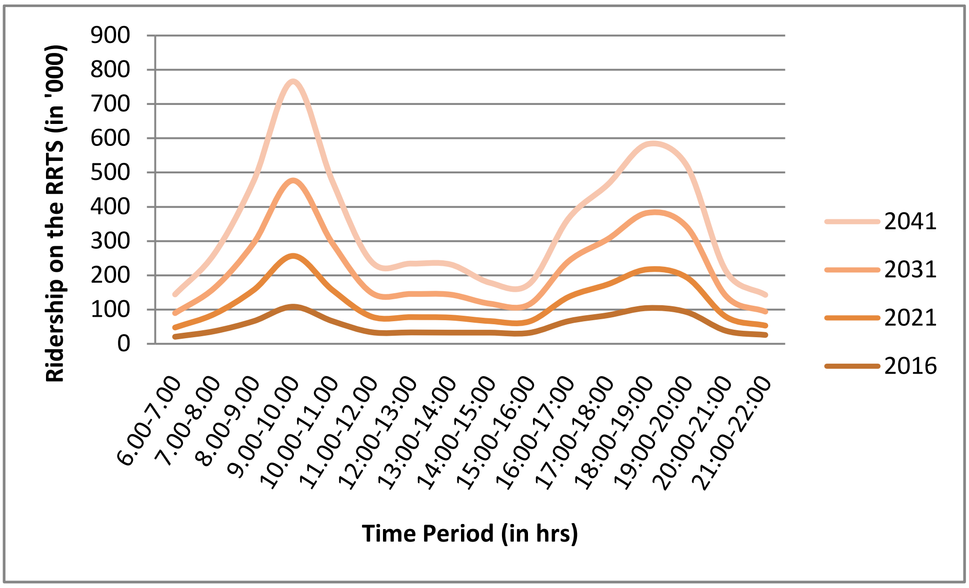
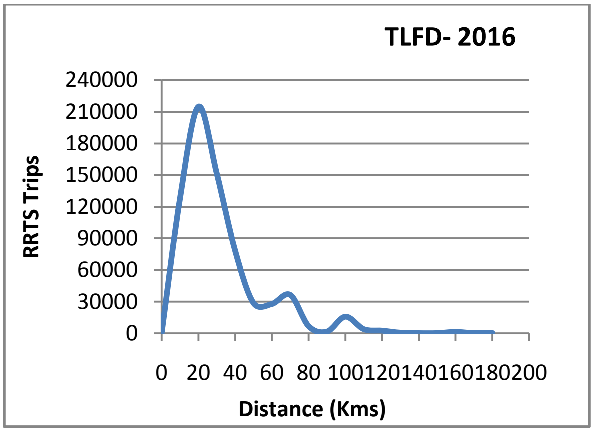


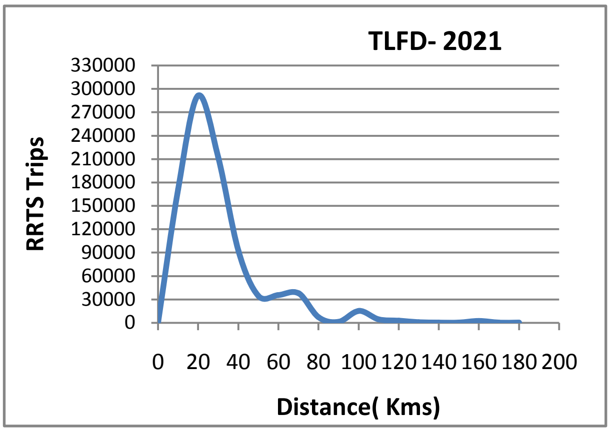
Figure 2-5 – Hourly Variation (Alwar to ISBT Kashmere Gate)

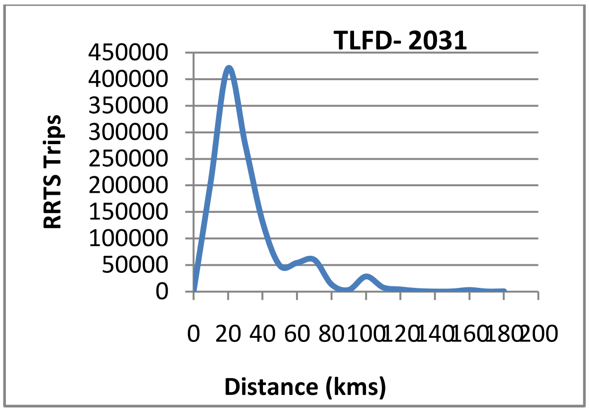
It is seen that the traffic in both the directions reduce to a minimum after 11 PM, indicating the operation time period for the RRTS trains.

2.5.4 Average Trip Length Distribution

The figures below show the average trip length of RRTS. It can be seen that the majority of trips on the RRTS will have a travel distance of more than 20 kilometres in the horizon years.







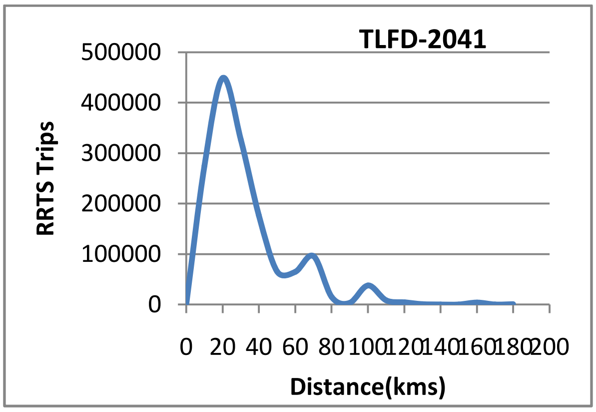


Figure 2-6 – Trip Length Frequency Distribution (All horizon years)

As per the assignment model estimation, there are also around one lakh trips which have a trip length of more than 60 kms and around 50000 trips of more than 100 kms by 2041. The Table 2-7 shows the average trip lengths for the various horizon years.

Table 2-7: Average Trip Length

Year	Average trip Length (in kms)
2016	27.42
2021	25.96
2031	27.69
2041	28.78

2.6. Optimistic and Pessimistic Scenarios

The finalized alignment has been tested for both the optimistic and pessimistic scenarios with TOD for the years 2016, 2021, 2031 and 2041. The daily ridership comparison for three scenarios is presented in Table 2-8 and the traffic for the three scenarios for the final RRTS alignment shown in Figure 2-7.

Table 2-8: Daily Ridership comparison

DAILY RIDERSHIP (IN LAKHS) - FINAL ALIGNMENT			
YEAR	OPTIMISTIC	REALISTIC	PESSIMISTIC
2016	8.06	6.99	5.96
2021	10.38	9.12	7.78
2031	14.18	12.55	10.69
2041	16.98	15.10	12.79

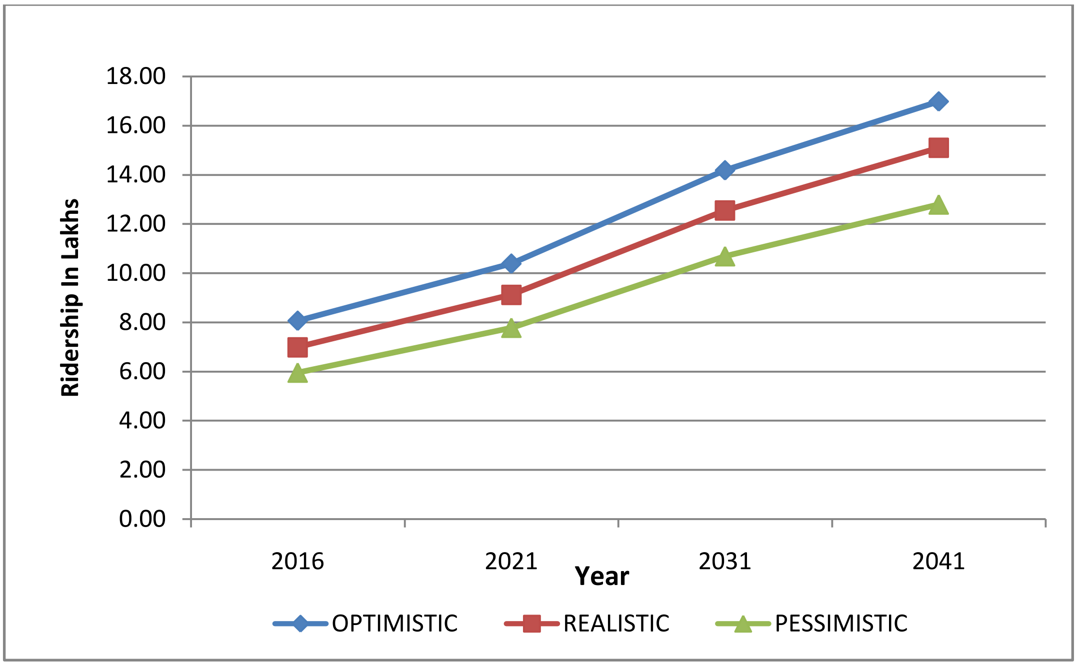


Figure 2-7 – Traffic Comparison-Optimistic, Pessimistic and Realistic Scenarios

2.7. Final summary

Ridership summary for the RRTS is presented in Table 2-9

Table 2-9: Ridership for various Horizon Years (Realistic Scenario)

Description	2016	2021	2031	2041
Peak Hour Candidate Trips	979738	1247178	1515061	1798448
Peak Hour Diverted Trips	69920	91321	125593	151135
Daily Ridership on RRTS	698330	912490	1255410	1510660
Maximum sectional load	13792	15646	21817	25775

The rolling stock requirement and the train operation plans for the horizon years have been worked out on the basis of this above data.

3. System Selection

3.1. Introduction

The objective of RRTS is to cover a distance of about 180 km between Delhi and Alwar via important traffic generation nodes, for the commuters to complete their journeys in a reasonably short time, at a reasonable fare and with reasonable comfort, so that they need not reside at their places of work. The RRTS has to be fast, safe, reliable and should provide uninterrupted service so that private car users particularly, shift to RRTS for their daily commute on business and recreational trips or for education purposes etc. RRTS should help in reducing population pressure on Delhi and relieve roads in NCR from further congestion due to plying of private vehicles. The journey between Delhi and Alwar or vice versa should be completed in about two hours, then only the RRTS service would be attractive and successful. The concept would have to be different from the high speed trains which have very limited stoppages en route, as RRTS would have to serve the commuters with stoppages at all traffic generation points, identified in the Travel Demand Forecast studies. At the same time the metro rail type service will also be inadequate due to its low average speed, in the range of 30 to 35 kmph, and stoppages at an average distance close to one kilometre.

3.2. System Specifications

The rail based transit technology is now well developed and is capable of providing solutions to a wide range of city and sub-urban transport problems in different situations. Various standard components of the system such as guide-way, rolling stock, signalling and telecommunication systems, fare collection system etc. can be so combined as to have a system to meet the desired requirements. The most suitable technology for the various sub-systems of the RRTS to match the desired objectives has been discussed in depth in various Consultancy Review Committee meetings set up for the project, and the high level Task Force, and concrete decisions have been arrived at. These are briefly touched upon in the following paragraphs. The details of all sub-systems have been covered in the relevant chapters of the report.

Track Gauge – 1676 mm Broad gauge is the national gauge of India, and the same will be adopted for RRTS. RRTS being commuter rail system two separate tracks would have to be laid for directional traffic, one line carrying trains from Delhi towards Alwar and other line from Alwar towards Delhi. Track structure and geometric parameters have been discussed in the relevant chapter.

Traction System and Rolling Stock– 1x25 kV and 2x25 kV single phase AC overhead catenary systems were debated and finally it has been decided to adopt 1x25 kV AC single phase 50 Hz overhead catenary traction system.

Air-conditioned light weight stainless steel Electrical Multiple Units will form the rolling stock for the RRTS, each unit of three comprising of two motor cars and one trailer car. 6 car trains with DMC-TC-MC-MC-TC-DMC composition will be introduced on commissioning of the RRTS.

Signalling and Train Control System – Continuous Automatic Train Control System will be provided to maintain the desired frequency of trains.

Radio based TETRA and Optical Fibre Cables (OFC) will be used for the telecommunication and passenger information system.

Automatic fare collection system, which can be integrated with Common Mobility Card, should be provided.

The operating speed of the trains will be 160 kmph with design speed of 180 kmph. This will be a passenger only system and no freight trains shall be operated on these lines.

All trains will operate at similar speeds, and the precedence will be rare only when there is any failure of rolling stock or any other unusual occurrence, that too will take place only at stations provided with crossover facilities.

Civil Engineering and other constraints - The alignment of RRTS has been described in detail in Chapter 4. Briefly speaking there is no land available in NCT Delhi. Therefore, RRTS tracks cannot be laid at grade in NCT. Also the roads in the alignment of RRTS are provided with a number of flyovers, and there are skyline related issues in the city. Therefore, laying RRTS elevated in NCT is not feasible. Hence there is no option but to carry the RRTS underground within the NCT and upto IFFCO Chowk in Gurgaon due to constraints imposed by the building line and the high voltage transmission lines near Cyber City. After IFFCO Chowk the alignment will be ramped out to become elevated, and the next station at Rajiv Chowk (G) is proposed to be elevated. The alignment till Dharuhera will run on the service road or the median of national Highway – 8, from where it will turn to left to reach BTK in Rajasthan. It is proposed to carry the alignment elevated throughout till Alwar. There is a possibility to lay the RRTS tracks at grade between BTK and MBIR, and then from SNB to Alwar. Though carrying the alignment at grade is cost effective, it has many disadvantages, and operational and safety issues, which have been elaborated in the concerning chapter. As the principal objective of the proposed RRTS is to provide safe, reliable and uninterrupted commuter services, laying RRTS at grade is not recommended.

Location of Stations - Stations have to be located so as to serve major passenger origin-destination points, and to enable convenient integration with other modes of transport for inter-changeability. However, to provide a fast service it may not be possible to have the stations at close intervals, like Metro services. If the stations are located too close an interval the system cannot provide fast services and the purpose of RRTS may not be served. Interchange facility with a number of Delhi Metro stations has been envisaged in NCT of Delhi. Attempt has been made to locate other stations also in the transport zones. It is proposed to categorise the stations on the RRTS, based on the traffic demand, requirement of passenger interchange facilities and other operational facilities, into following types:

Type ‘A’ stations - Terminal Stations

Type ‘B’ stations - Important stations having facilities of interchange from RRTS to other modes of transport

Type ‘C’ stations – All other stations on the route.

3.3. System Specification Summary

The System specifications, as finalised after detailed deliberations in various CRC meetings are tabulated in the Table 3-1 below:

Table 3-1: System Specifications

S.N.	Important Parameters	Accepted by Task Force
1.	No. of lines • Main	One, Siding would be proposed in the Feasibility Report appropriately.
	• Spur	Deleted after discussion on 30.08.2011
2.	Gauge	Broad gauge (1676 mm)
3.	Class	One (Only AC)
4.	Rolling Stock Type	EMU, Light weight stainless steel coaches
5.	Coach Dimensions	3.66 m wide and 24 m long
6.	Coach Features	
	a) Coach capacity	226 passengers for Train operation plan
	b) seating style	Front/rear facing (2+3)
	c) Standing	Allowed
	d) No. of Decks	Single
	e) Space for toilets	No
	f) Space for wheelchair	Yes
	g) No. of Doors	Three doors a side
7.	Axle Load	20 tonnes
8.	Train Composition	2X3 car units for 6 coach trains upto 2030 and 3X3 car units for 9 coach train from 2031.
9.	Max. Operational Speed	160 Kmph
10.	Design Speed	180 Kmph
11.	Acceleration/Deceleration / Emergency Braking (m/s^2)	1.0 (a) / 1.0 (d) / 1.3 (e) m/s^2
12.	Traction Type	1x25kV AC
13.	Signalling System	CATC - 3G[1] It may be reviewed at the time of bidding in favour of communication based system, if implemented successfully and running somewhere in the World for reasonable time.
14.	Telecommunications	Radio based TETRA and OFC.
15.	Fare collection system	Automatic
16.	Platform Length	Platform length would be requirement of coaches for the year 2041+ 3 coach to provide scope for expansion beyond 2041 i.e. 12 coaches.
17.	Toilet Location at station	Inside paid area

[1] Spectrum not required. Metro is using CATC

4. Civil Engineering

4.1. Introduction

Generally high speed / rapid rail based transit systems are provided with grade separation from the surface to avoid any cross traffic. This can be achieved most effectively either by underground system or elevated system.

However there are significant cost advantages of other options viz. At-grade system and semi-elevated system, which is a middle path between an At-grade system and elevated system.

The salient features of these alternatives are described below:

4.1.1 Underground System

Underground system is adopted in stretches where adequate land is not available for construction of a system on the ground or as an elevated one, and where environmental or aesthetic considerations do not permit over ground lines. In this system, the railway lines are constructed below ground level either by cut and cover method or by tunnelling method. The area is excavated in the shape of trenches and formation is made ready, track is laid, overhead traction power lines are provided and finally the trenches are covered and ground restored in the cut and cover method. However in the tunnel section, the underground railway is taken deep below the ground through tunnels which are bored using modern tunnel boring machinery or with NATM technology.

In this system, the underground railways are provided at a depth which is generally more than 10m deep. The railway line is constructed in a tunnel, the shape of which is circular or a tube, and hence the name tube railway. The main reason of taking the railway so deep i.e. more than 10m, is to avoid interference with water supply mains, sewerage system, telephone lines, gas line, etc. which normally exist within 10 m of natural ground. However the actual depth to be adopted will depend on existing underground facilities like roads subways, underground metro lines etc., which will require to be crossed.

Normally, electric traction is used in such systems to avoid smoke and environmental pollution.

Escalators, lifts and staircases are provided for facilitating passenger entry and exit. In order to provide safety to passengers the doors of the compartments have to be closed before trains can start.

The main advantages of the underground system are that train services can run unobstructed as there are no road crossings or such other similar problems. No land on surface is occupied and large area of the cities, which would have otherwise been used for surface railways, are available for better land use. This system also provides safety during aerial attacks particularly during war.

The main limitation of an underground transit system is that it is a very costly system and requires heavy financial resources. Also special care has to be taken for effective drainage and ventilation of the underground system. During construction stage, many essential services have to be diverted causing inconvenience to the residents of the areas where the construction is taking place, during the construction period.

4.1.2 Elevated System

This type of railway system is provided at an elevation above the ground level. The track is laid on a deck which is supported by steel or RCC columns. The platforms and even the station buildings are provided at an elevation for the convenience of the passengers.

The track is generally constructed, at an elevation of at least 8m above ground or road on a viaduct. It is to be ensured that the required clearances are maintained to provide for road and waterway crossings.

The elevated railways have an advantage that no separate land is required for the same as the track and other structures are at an elevation. There is no interference with the road traffic as the road may be passed through between the columns. Such elevated railways are normally provided with columns on the central verge of the road and therefore the system can be laid even in busy areas. Cross roads can also pass below the elevated structure which avoids the construction of separate road over / under bridges.

The limitation of elevated railways is that they cause noise pollution because everything is in the open and further, in the case of accidents on elevated railways, the handling of emergencies is more difficult, requiring meticulous rescue arrangements.

The elevated viaducts generally consist of simply supported spans with lengths of about 20-30m.

4.1.3 At-Grade System

This is the least expensive and least time consuming system from the capital cost and construction time perspective, provided the land is available at affordable cost. The At-Grade railway lines are generally preferred in open country side where there is no constraint of availability of land and the possibility of encroachments close to tracks is minimal. However, it has many disadvantages with regard to its maintainability and operational safety, which are briefly discussed below:

4.1.3.1 The At - Grade alignment will require acquisition of a wide strip of land, depending on the topography of the area and the permissible gradient of the line. The land requirement is substantial in comparison to the elevated alignment. Acquisition of land is a painful process and litigations cannot be ruled out, which may affect the construction schedule of the RRTS adversely.

4.1.3.2 The RRTS corridor should not have any rail-road level crossing. All such crossings, which will be large in number, will need to be grade separated, and the RRTS tracks will have to be raised, or the road will have to be lowered, at all such road crossings, involving construction of large number of Road Over Bridges/Road Under Bridges.

4.1.3.3 The At-Grade length of the RRTS would need to be fenced with strong concrete walls on both sides, as no trespassing or grazing of animals in the RRTS ROW can be allowed, to enable fast and unhindered movement of trains at a high frequency of the order of 5 minutes and an operational speed of 160 kmph. Running over of animals by the train may result in derailment of train. Sometimes herd of wild animals come over the track, particularly in the early and late hours of the day. It has been observed and experienced on Indian Railways that such fencings do not last long and the people living in the nearby area break/damage them frequently, as these fencings divide the country side. Even the unauthorised crossing of waterways by persons and animals through the railway bridges cannot be prevented, which is very risky for the train operation as well as for those using the railway bridge for crossing.

4.1.3.4 In At - Grade alignments the theft of fittings from track is quite rampant and the consequences of sabotage are also grave, causing potential danger to the safety of trains and passengers.

4.1.3.5 Throwing of stones on the trains is quite common. When a train passes through inhabited areas the children throw stones on the train, which often result in breakage of glass windows of the train and sometimes may hit the passengers.

4.1.3.6 Operation during foggy weather is likely to be seriously hampered, due to low visibility and uncertainty about the obstruction on the track ahead.

4.1.3.7 At grade track will be ballasted unlike the ballastless track of elevated or underground track laid on the concrete slab and plinth beams. Ballastless track is not suitable for laying on earthen formation, as the concrete slab is quite likely to crack and give way due to settlement of formation. Ballasted track requires more intense and frequent maintenance, such as tamping by machine, periodic ballast replenishment and cleaning, drainage etc. Maintenance of track in RRTS cannot be done during day time, and the maintenance hours are limited to 4-5 hours during night. A good lighting system on the track would be necessary for track tamping and ballast cleaning during night. It will also necessitate heavy investment on purchase and upkeep of track machines.

As the principal objective of the proposed RRTS is to provide safe, reliable and uninterrupted commuter services, laying RRTS at grade is not recommended.

4.1.4 Semi-elevated System

The semi-elevated system is gaining popularity since the embankment up to 2.5m high, which is usually adopted, does not require costly concrete structures.

All village and colony roads having only LMV traffic/Tractors and Bullock carts can be passed through the openings in the embankment without any re-grading of tracks. The raising of tracks is required where National Highways, State Highways and roads having truck and bus traffic have to be crossed and the required clearances have to be provided.

These vertical walls of almost 2 m high also protect the line from tress passing by cattle, men and tractors / carts, increasing the safety of the trains. In developing areas, it is usual to leave openings to enable crossing by light vehicles, cycles, rickshaws, carts and tractor trollies every half a Kilometre or so.

However, this system when used in green field and developing areas will limit the scope of growth and in case the traffic, on roads where only 2.5m clearance is provisioned, increases it may not be possible to re-grade the track at a later date to create grade separators either ROB/RUB.

Though with the development of appropriate technology and design, huge quantities of earthwork in side slopes of embankment can be saved by using precast reinforced concrete wall panels, besides minimizing the land requirement; on such track, usually ballasted track has to be provided which requires frequent replenishment of ballast and machine tamping, requiring heavy investment on machines.

Also, if the number of high clearance openings is large, the ride would be similar to a roller coaster and hence be uncomfortable for the passengers. Also, the cost saving would drastically come down as the high clearance openings would be similar to elevated viaduct / Road bridge.

Hence, this system of alignment is also not recommended for the proposed RRTS system.

4.2. Alignment Description

The RRTS alignment is proposed as a Broad Gauge electrified double line, along the grades, detailed below, as required by the terrain and prevalent conditions to provide the most economical facility.

4.2.1 ISBT Kashmere Gate – New Delhi

The RRTS facility is proposed to originate from an underground station below St. Stephens ground and Agrasen park, adjacent to the existing DMRC Kashmere Gate Station. Integration is also proposed with the DMRC station and Delhi – Panipat RRTS Station.

From here, the alignment will run below Kutcheri Road behind Tis Hazari courts, through a 6 degree (290 m radius) curve, and proceed under the Naya Bazaar and Shradhanand Marg upto Ajmeri Gate, from where it will enter the proposed New Delhi RRTS Station below Bhavbhuti Marg.

The Right of Way of these roads is adequate for the RRTS tunnels. The Northern Railway main line tracks from Shakur Basti / Sabzi Mandi to Delhi Main Station will be crossed by the underground tunnels near the Duffrien Bridge. Other utilities coming in the way of the alignment will be suitably shifted or protected during the construction phase. The only structures coming on the alignment are on both sides of the Northern Railway lines from Delhi Main Station. These structures are not multi storey construction and may not be required to be disturbed during tunneling.

4.2.2 New Delhi – Sarai Kale Khan Section

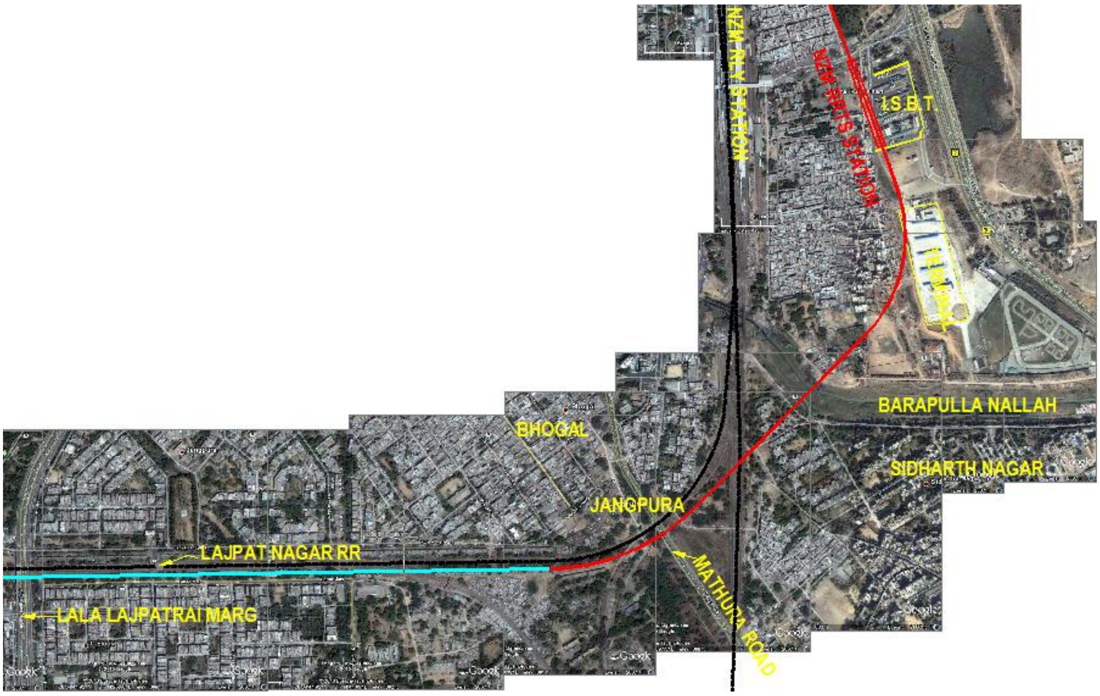
The next station of the RRTS will be on the eastern side of the New Delhi Railway Station below Bhavbhuti Marg parallel to the DMRC Airport Express Line and is proposed to be constructed underground next to the bus shelter between the existing New Delhi Railway station and the Multi level parking.

Exits from the station are proposed towards New Delhi station in the Ajmeri Gate forecourt, across Bhavbhooti Marg for connection towards Kamla Market, as well as near Shivaji (Minto) Bridge for direct entry from Indira Chowk (Connaught Place) side.

Since the station is proposed in the close vicinity of the new multi level parking facility created opposite New Delhi Railway Station, RRTS users will also be able to make use of this parking facility.

As stated earlier, the alignment will run underground below Bhavbhuti Marg and continue southwards towards Crowe Chowk. At Crowe Chowk, the alignment will turn eastwards and run below Deen Dayal Upadhyay (DDU) Marg. The alignment will proceed under DDU Marg till it crosses the School Lane fly-over and from here it will turn with suitable curves to Mahawat Khan Road behind Andhra School and will cross Bahadur Shah Zafar Marg, parallel to the Tilak Bridge.

From Tilak Bridge, the alignment will continue between the Railway road, serving COFMOW and other Railway offices, and the storm water drain. The track would go below the existing DMRC's NOIDA Line, and then run below the Ring Road (Mahatma Gandhi Marg), right up to the Sarai Kale Khan ISBT where the underground Sarai Kale Khan RRTS station is proposed to be located.



4.2.3 Sarai Kale Khan – INA Section

After Sarai Kale Khan Station, the alignment will take a westward turn passing under the existing Northern Railway main line tracks to Faridabad / Agra and will there after run parallel to the existing Ring Railway up to Lajpat Nagar Ring Railway Station.

At Lajpat Nagar ring railway station the alignment will also pass across to the southern side of the Delhi Avoiding Line (DAL) coming from Tughlakabad. From here it will run parallel to the Ring Railway through Sewa Nagar and Lodi Colony Railway Stations. RRTS will also cross the Central secretariat – Badarpur DMRC line between Jungpura and Lajpat Nagar stations.

The INA RRTS station is proposed under the Safdarjung Bus Terminus between the Lodi Colony Station and the Safdarjung Airport flyover along Aurobindo Marg.

4.2.4 INA – Dhaula Kuan Section

After the INA RRTS station, the alignment will pass under the Gurgaon – Central Secretariat DMRC line running under Aurobindo Marg.

After Safdarjung Airport, the alignment will continue along the Ring Rail passing alongside Sarojini Nagar and Delhi Safdarjung Stations. From here, it will turn southwards along Delhi University South Campus. Dhaula Kuan RRTS station will be located on the eastern side of Atma Ram Sanatan Dharam (ARSD) College.

4.2.5 Dhaula Kuan – Mahipalpur Section

From Dhaula Kuan the alignment will run behind the compounds of the South Campus of Delhi University, crossing Rao Tula Ram Marg and running parallel to it and then turning westwards to meet the National Highway – 8, near Naval Officers Mess.

Due to lack of land availability between the NH-8 and the Army area, it is proposed to take the RRTS line under the service road of NH-8. The alignment runs along the eastern side of the NH-8 till it reaches the built up areas in Mahipalpur and then crosses over to the Airport side near Mahipalpur. This is necessary because in

Mahipalpur area there is no land due to dense habitation almost to the edge of the service road. After crossing Mahipalpur, the RRTS station is provided between the NH-8 and the Airport boundary.

4.2.6 Mahipalpur – Cyber City Section

After Mahipalpur Station the alignment will cross the exit ramp of the elevated road from NH-8 to the IGI Airport before crossing back to the eastern side of the NH-8, while going towards Cyber City, Gurgaon.

After crossing the Delhi – Haryana Border the alignment continues to run under the service lane of NH-8 up to the Toll Plaza. Near the Toll plaza the alignment passes through the Dhanchiri Tourist Camping Ground of Haryana Govt.

The Alignment continues under the service road along NH-8 after the Dhanchiri Camp. This is due to the location of Rapid Metro Rail and the HSEB having recently erected pylons for running a HT line in the green belt. The Cyber City station will be located in green space adjacent to NH-8.

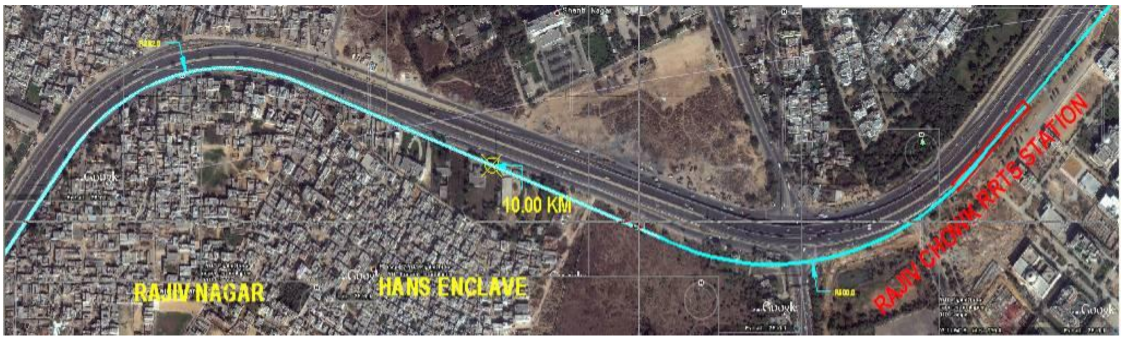
4.2.7 Cyber City – IFFCO Chowk Section

From Cyber City the line will continue to run underground in the green belt along NH-8 up to IFFCO Chowk and after crossing Westin Hotel, the IFFCO Chowk station will be located in the green belt of the NH.

This station is so located with a view of its integration with the existing IFFCO Chowk DMRC station and the proposed DAMEL station after the extension of the DAMEL from Dwarka Sec 21 to IFFCO Chowk.

4.2.8 IFFCO Chowk – Rajiv Chowk (Gurgaon) Section

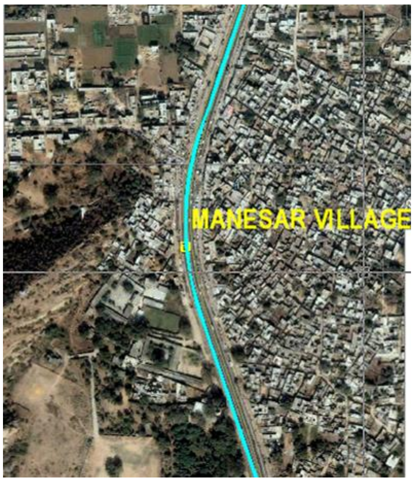
After IFFCO Chowk station that alignment will continue to be underground till crossing the road intersection near Hotel Crowne Plaza and then it will start to ramp up. The alignment will come overground and become and elevated line near Star Mall (opposite to 32nd Milestone restaurant)



and proceed towards Rajiv Chowk. The Rajiv Chowk station will be located between the Jharsa Road-NH8 intersection and Rajiv Chowk. The station area is located on a straight portion before the road arcs at Rajiv Chowk area.

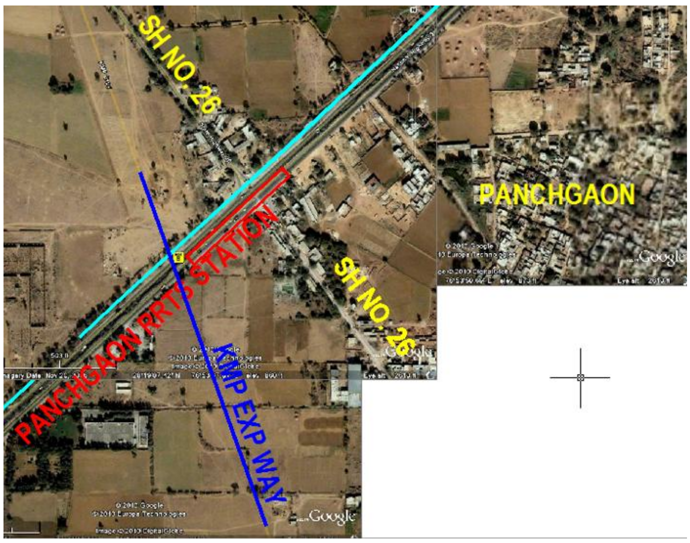
4.2.9 Rajiv Chowk (Gurgaon) – Manesar Section

From Rajiv Chowk, the elevated line will move onto the central verge of NH-8 and will continue up to the 2nd Toll Plaza, on NH-8, near Khirki Daula village. This is necessitated due to lack of space on the service road along NH-8 in this section. Near the 2nd toll plaza, the alignment will move back to the service road.



The alignment will continue along the NH-8 and cross Lakhnaula village and proceed to Manesar. Manesar RRTS station is located north of Manesar Village in the green belt area of NH-8, near the new residential sectors of Manesar.

4.2.10 Manesar – Panchgaon Section



From Manesar, the alignment will run elevated on the central verge of NH-8 through the congested Manesar village, across the Aravalli Range and alongside the National Security Guard (NSG) Camp. The alignment will continue on the central verge after crossing NSG camp area also, as the hilly terrain of the Aravalli Ranges on either side of the NH-8 in this section prevent the alignment from being constructed on service road.

After crossing the Aravalli Ranges the alignment moves back to the service road on the eastern side of NH-8. Panchgaon RRTS station is proposed short of the crossing of Kundli-Manesar-Palwal (KMP) Expressway over NH-8.

4.2.11 Panchgaon – Dharuhera Section

The elevated alignment will pass over the KMP Expressway. After Panchgaon the alignment will run elevated up to Bilaspur Kalan village after the Old Toll Plaza (now dysfunctional) before Dharuhera town on the green belt and from there it will move away from NH-8 and onto the new roads proposed in the Land Use Plans.

The Dharuhera RRTS station is proposed in the Transport Land Use Area as earmarked in the Master Plan.

4.2.12 Dharuhera – BTK (Bhiwadi-Tapukara-Kushkera) Section

After Dharuhera Station, the alignment will run elevated over the Master Plan roads planned in the area before crossing NH 71B and will enter Rajasthan state via SH-25 (Tijara Road).

The alignment will run southwards on SH-25 (Tijara Road) up to the transport land use area earmarked in BTK Complex, near the proposed DFC alignment. The BTK RRTS Station is proposed to be located here.

4.2.13 BTK – MBIR (Manesar Bawal Industrial Region) Section

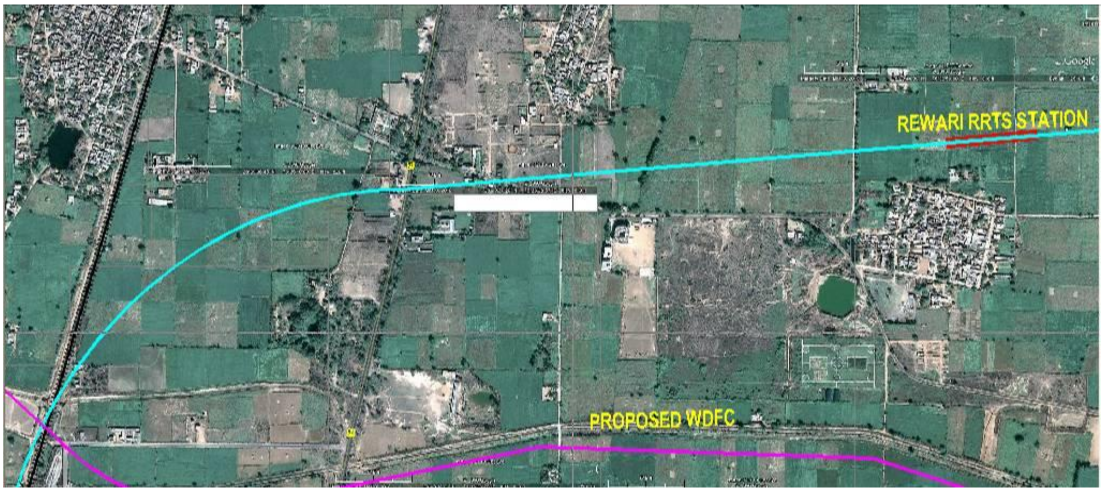
From BTK the alignment will leave SH-25 and move westwards towards Rewari. The alignment will pass through agricultural fields running north of the DFC alignment and the proposed Inter Modal Logistics Hub being constructed as part of the DMIC plans. The alignment crosses NH-8 and passes to the north of Churiawas village. MBIR Station is proposed to be located adjacent to NH-8 on its western side.

4.2.14 MBIR – Rewari Section

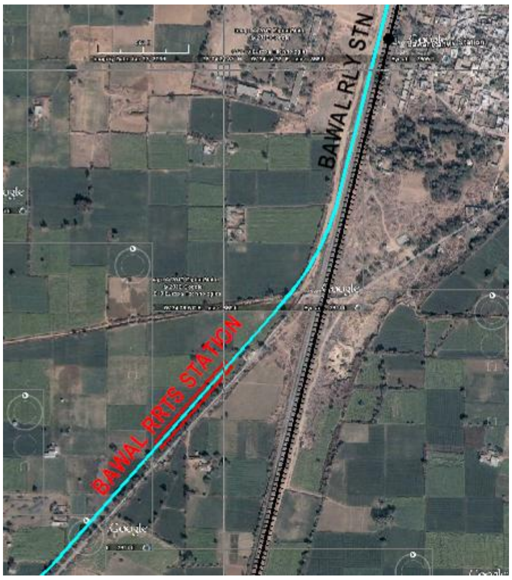
After crossing the MBIR Station the alignment will first run through the planned sectors, and will then run along the Outer Ring Road as per Master Plan of Rewari.

As the orientation of the roads proposed in the Rewari Master Plan is not in conformity with the RRTS alignment, it will have to cut across the proposed sectors. The consultant would recommend modification of the Master Plan to match the RRTS alignment. Otherwise, the RRTS line will have to be taken underground in this stretch.

The Rewari RRTS Station will be located in the transport land use area earmarked in the Master plan, south of Gajjiawas Village.



4.2.15 Rewari – Bawal Section



After Rewari station the alignment will cross the proposed DFC alignment and the existing Indian Railway (IR) line while turning southwards. The alignment will run on the western side of the IR line towards Bawal. Ahead of NH-8, the alignment will deviate slightly and go around the Chirahada and Rudh Villages existing along the IR Main Line.

After crossing the NH-8, the alignment continues to run parallel to the IR line till it crosses the existing Bawal Township and the proposed residential sectors. The Bawal RRTS Station will be located south of the planned residential sectors in Bawal.

4.2.16 Bawal – SNB (Shahjahanpur-Neemrana-Behror) Section

After crossing Bawal station, the elevated alignment will proceed southwest, moving away from the existing IR line, towards NH-8. Just before NH-8, near Shahjahanpur, the alignment will turn back towards Southeast and will run through the proposed Transport Land Use area, which is presently agricultural, and the SNB station will be located here to serve the upcoming industrial zones.

4.2.17 SNB – Khairtal Section

After SNB station the alignment will move eastwards towards the existing Indian Railway track and will thereafter run parallel to it.

The alignment will cross the Sahibi Nadi through a major bridge (approx. 600m waterway) parallel to the bridge on existing IR line and run up to Pataliya Village. Beyond, the alignment will deviate from the IR alignment due to congestion and lack of space in Khairthal town. The alignment will pass along the Khairthal Bypass Road proposed in the Master Plan.

The RRTS station will be located close to the intersection of Khairthal - Alwar Road and the proposed Master Plan Road.

4.2.18 Khairtal – Alwar Section

The line will run southeast towards the existing IR line and come adjacent to it at near Vallabhgram Village and thereafter run parallel to it up to about 5.5 kms north of the existing Alwar IR Station from where the alignment will cross onto the eastern side and move towards the Alwar bypass road (SH 25). The alignment will cross the Alwar - Tijara Road and the Alwar - Mathura IR line. The RRTS station is proposed on SH-25, near the Ansal Township.

Alwar RRTS station has been located keeping in mind the master plans and expansion proposed for Alwar City.

Table 4-1: Standards for Permanent Way

S. No.	Item	Description
1	Rails	60 kg UIC head-hardened rails on main line and 52 kg 90 UTS rails for the depot area
2	Sleepers	PSC Sleepers at 650 mm centres on ballasted track in depot area
3	Track Structure	Ballastless track will be provided on elevated and tunnel sections with fastening spacing at 600mm centres In depot area, Ballasted track with 300 mm. cushion of stone ballast below sleeper as per RDSO specifications
4	Points and Crossings	1 in 8½ in depot and yards, and 1 in 12 Points and Crossings on running lines. All points & crossings will be provided with CMS crossings and thick web curved switches

4.3. Design Norms – Track Geometry

Track geometry is very important from the point of view of speed, safety, maintainability and passenger comfort.

The norms of track geometry which are planned to be adopted are described below

4.3.1 Ruling Gradient:

The stations will be kept on a level stretch. In any case where unavoidable, the IR / DMRC stipulation of stations not being on a grade steeper than 0.1% will be followed.

The maximum gradient in mid section will be kept at 2% and in exceptional locations it may go up to 4% including curve compensation.

4.3.2 Curvature:

The limiting curvatures that have been proposed are as under:-

Horizontal Curves

Minimum curve radius at stations	:	1000m
Minimum curve radius in mid section	:	290m
Maximum permissible cant	:	165mm
Maximum cant deficiency	:	100mm

Vertical Curves

Radius on Main line minimum	:	1500m
Radius on main line desirable	:	2500m

4.4. Fixed Structure Clearances:

All fixed structures provided on the line shall have clearances conforming to the recommended Schedule of Dimensions 2004 of Indian Railways to suit 25 KV AC Traction. As regards track centres, considering that the rolling stock will have closed doors, it is recommended to adopt track centres of 5 metres which will take care of the curvature of 290 m radius.

4.5. Station Area Planning

The Corridor Alignment Report (CAR) identifies the most suitable alignment and probable stations. The CAR also identifies the best possible location for individual stations (elevated or underground) based on station/section loads. The CAR calculated the increase in ridership and analysed the potential for Transit Oriented Development (TOD), including the area which can be developed above stations.

This report provides details on typical station design plans and sections (for underground and elevated stations). The analysis of Transit Oriented Development (TOD) around the station provides information regarding the approximate area that can be acquired, the conceptual site plan for the area and the various uses proposed with their ancillary requirements.

The typical station design includes the concept behind the station design, with design briefs and design breaks for various types of standard equipment. This includes the calculation methodology for platform sizes, parameters and assumptions, actual calculations and the approximate cost incurred. The typical station design basically provides details on the location of egress, paid/unpaid areas, ticketing system, areas and location for lift, escalators, Auxiliary Sub Station (ASS), etc. The station area planning process is shown in Figure 4-1.

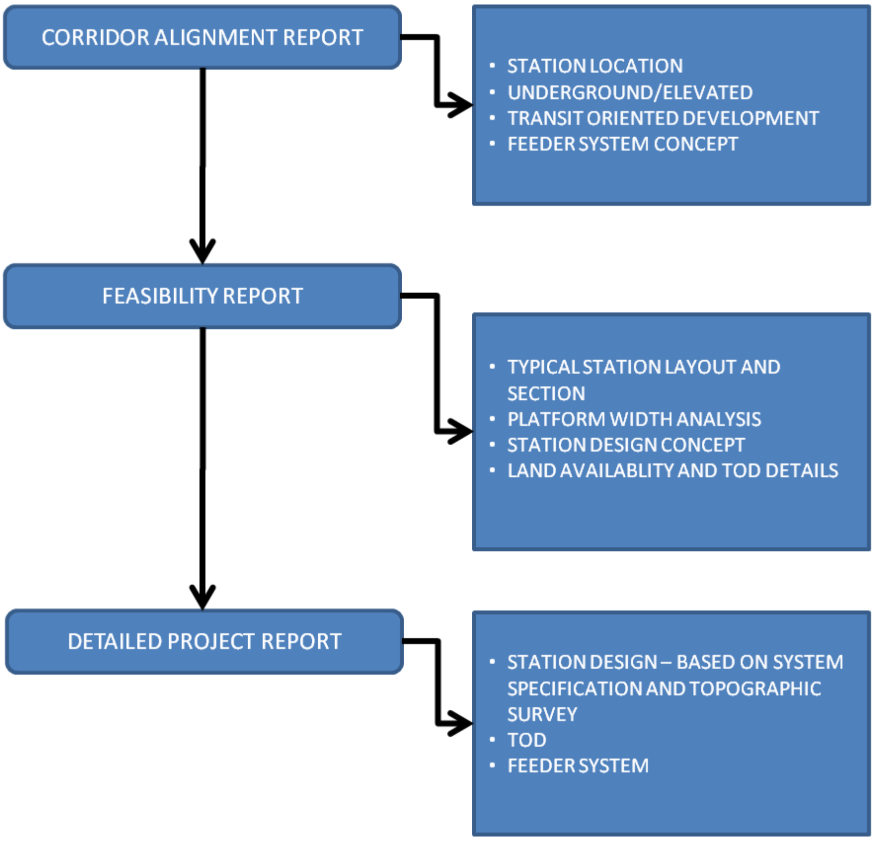


Figure 4-1 – Station Area Planning

The conceptual plan for the site for TOD includes: pick up/drop off locations for various modes; parking areas and capacity; different types of development; locations and floor areas to be developed; and, the final use matrix for the various uses and requirements.

The Feasibility Report also provides the approximate cost to be incurred for the respective TOD and stations. The feasibility report covers the following aspects of station planning as shown in Figure 4-2.

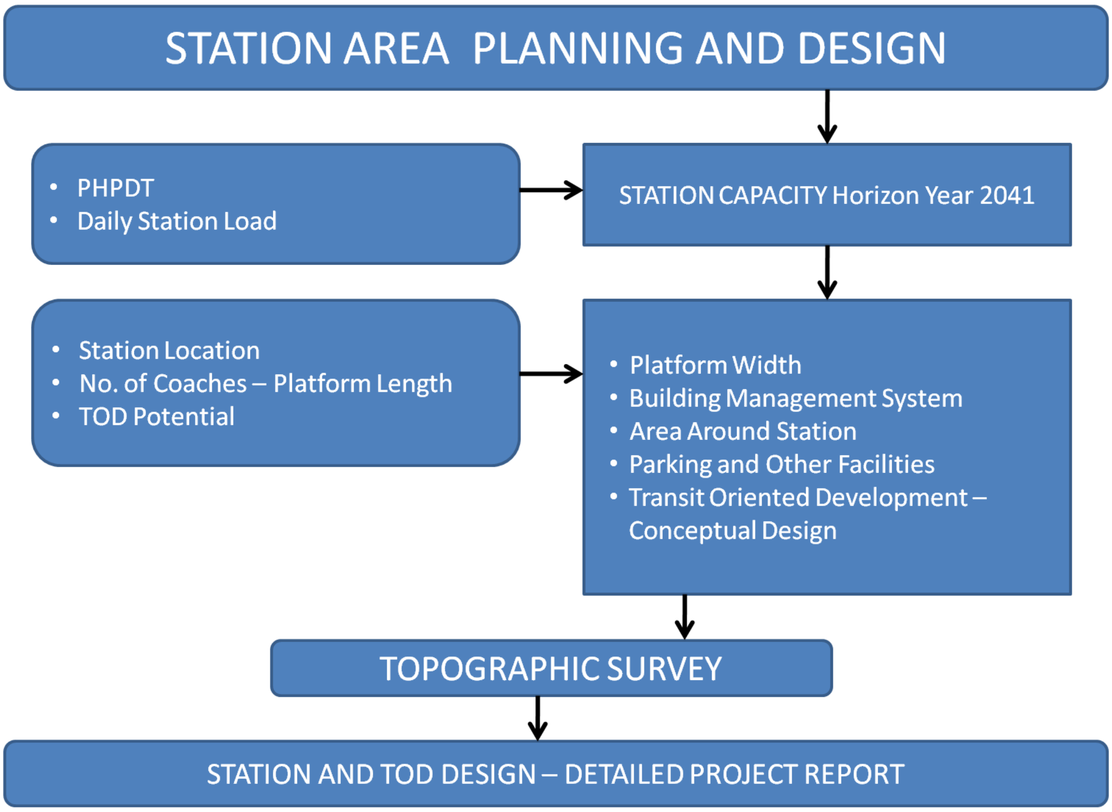


Figure 4-2 – Station Area Planning

4.5.1 Station Design Concept

Based on the study of various suburban systems across the world, the most preferable and suitable system for the ticketing is the controlled automatic fare collection system. This system allows for automatic gates to segregate paid and unpaid areas. The unpaid areas typically start at the entry and exit at the ground level for both underground and elevated stations and end after the ticket/token counters just before the automated gates, designed to open at the interface of token/RFID Cards. In addition to the segregation based on paid and unpaid areas, typical stations for elevated and underground have three levels – the Ground or Entrance Level, Concourse Level and Platform Level.

Entrance Level: The Entrance Level consists of entry gates, escalators, stairs and lifts. This level is generally on the ground floor and may have the token counters and automated fare collection gates.

Concourse Level: The Concourse Level is the interface between the paid and unpaid area and is the middle level between the entrance and the platform. For an elevated station, the concourse would be below the platform at a height of 4-5 meters above the ground level. For an underground station, the concourse is 3-4 meters below the entrance level.

Platform Level: The Platform Level is designed for passenger access to trains.

A typical station section would have either an island platform with tracks on both sides or two side platforms with the viaduct in between. For the island platform, all the ancillary services are in the centre opening at the Concourse Level and then are distributed on both sides of the station, ending at the road sides on the ground floor along the entry and exits.

Figure 4-3 to Figure 4-7 show the conceptual arrangement of movement areas, various levels and service areas in an underground and elevated station.

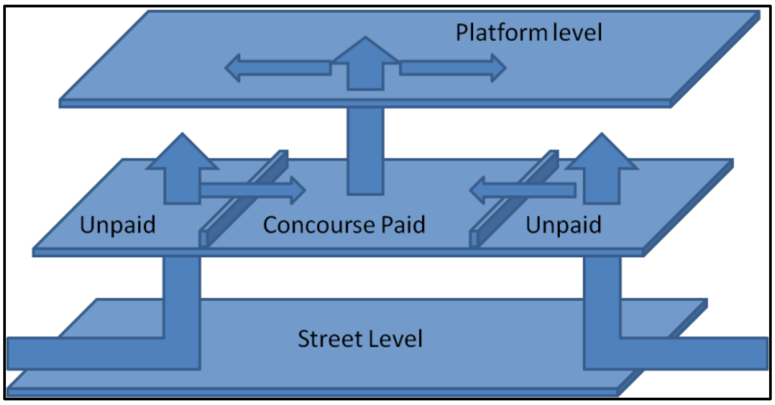


Figure 4-3 – Conceptual Movement Pattern Elevated RRTS Station

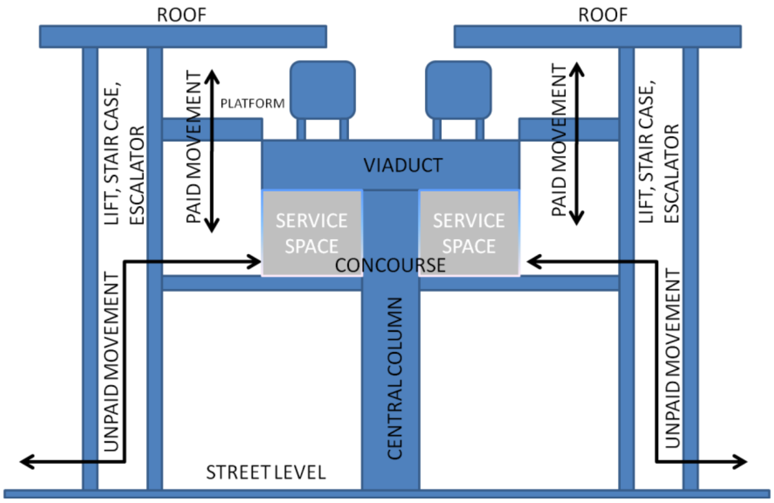


Figure 4-4 – Conceptual Elevated Station Section

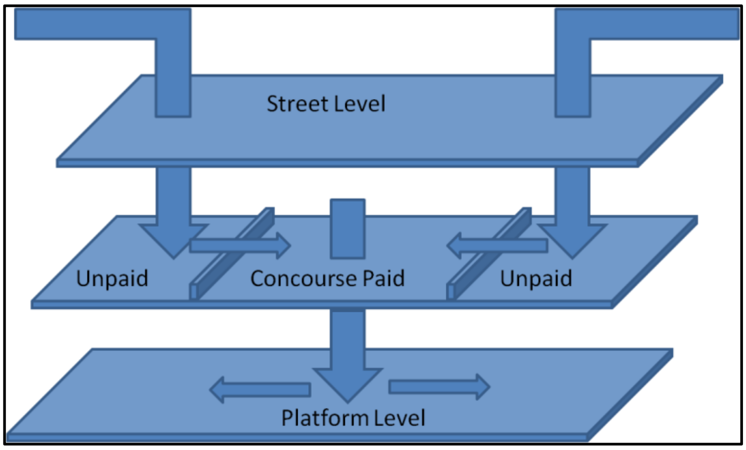


Figure 4-5 – Conceptual Movement Pattern Underground RRTS Station

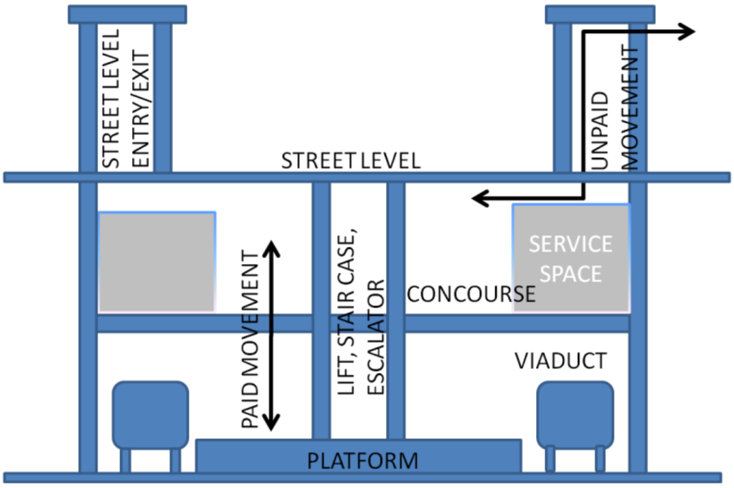


Figure 4-6 – Conceptual Station Section Underground RRTS Station (Island Platfrom)

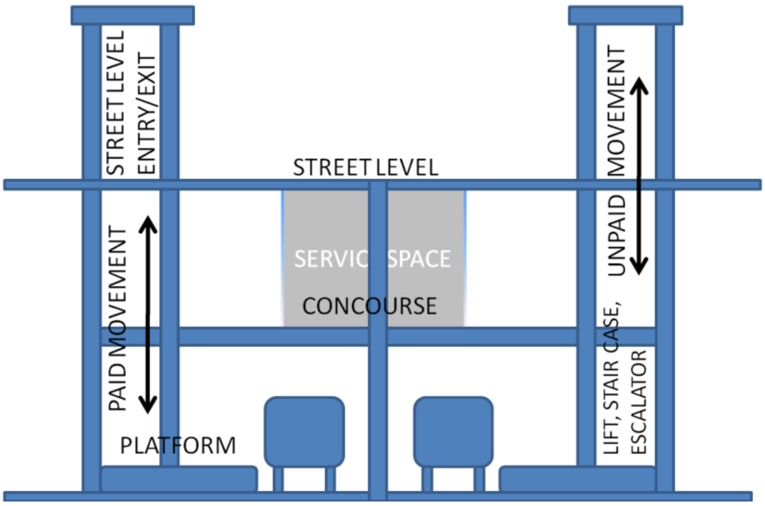


Figure 4-7 – Conceptual Station Section Underground RRTS Station (Side Platform)

4.5.2 Transit Oriented Development

Transit oriented development at depot and stations outside Delhi are proposed for revenue generation and long term sustainability of the corridor. The areas acquired would be developed on case to case basis with high density residential and commercial spaces. At Khairthal, land is earmarked for recreational hub. This report details out the approximate area that can be developed around the stations according to the land availability seen on the satellite imageries. Actual area calculations would be done at the DPR Stage. These TODs would be developed in a phased manner in the coming 10-15 years. Initially areas with high potential like Alwar, Dharuhera and Panchgaon can be developed. Then, Rewari and MBIR can be developed. Stations such as Bawal, SNB and BTK would be developed after analyzing the implementation of Master Plans of the respective urban areas. In the last leg of the TOD planning, areas like Khairthal can be developed.

The assumptions for area calculations for transit oriented development are as follows:

- The average height of development has been taken as 8 floors.
- The 70:30 composition of office is to retail space in commercial land use has been used.
- The 70:30 composition for saleable/leasable area and service area has been used for both commercial and residential.
- TOD level FAR will be around 2.0 – 2.5.
- The site plan level FAR averages approximately 3.2.
- Plot Level FAR would be around 4.0.
- The land acquisition for the raw land would be done based on the circle rates, with 20-25% variation while negotiations.
- The final FAR can only be ascertained at the DPR stage.
- Master Plan of cities of Haryana and Rajasthan are silent about parking norms. However, reduced norms with respect to Master Plan of Delhi 2021 (MPD – 2021) have been adopted presuming lower vehicle ownership in areas beyond Gurgaon towards Alwar. Parking has been calculated at 1.5 ECS for Commercial (2.0-3.0 ECS in MPD- 2021), 1.5 ECS (2.0 ECS in MPD – 2021) for Transportation and 1.0 ECS (2.0 ECS for Group Housing in MPD – 2021) for Residential purposes. However, for a High Density Development, these figures would be taken as low as 0.25 or 0.5 for the public parking spaces and higher for private parking spaces such as for offices, malls or housing.

4.5.3 Station Area Design Capacity Analysis Methodology

The platforms are designed based on the NFPA – 130 guidelines (National Fire Protection Act of the United States of America – 130). To calculate the peak platform load, the higher number between the Peak Hour Peak Direction (PHPDT) Load and 10% of the Daily Station Passenger Load has been taken for the horizon year 2041. The platform widths are calculated to accommodate two missed headways and a full train de-boarding with crush load. A single rake is considered to have 12 coaches (24m X 3.66m) and platform length is considered to be 320 m (Train Length – 288 m). The details of platform width calculations are listed below.

Platform width has been determined to cater to the greater of the following scenarios:

- ***Normal Service***

Normal operating conditions require a space reservoir for passengers waiting for a train. An average area of 0.5 square meters per passenger is considered desirable under these circumstances. The required platform width for the design peak condition has been calculated as follows:

Required platform width (in m) = 0.6 + (F x SI x 0.5) / PL

Where:

F = the peak one minute flow of boarding passengers entering onto a platform (i.e. wishing to travel in a given direction)

SI = service interval (minutes)

PL = platform length

The formula is based upon the assumption that a 600 mm wide zone adjacent to the platform edge will remain unoccupied when there is no train at the platform.

- ***Delayed Service***

The minimum platform width shall also be checked against the following criteria for a delayed service scenario. For an island platform, the area between the boundaries of the two platform faces can be included in the calculation.

a) A delay in service of 2 missed headways is assumed in one direction in the peak hour. Therefore 3 headways of accumulated passengers are gathered on the platform.

b) A full crush loaded train is required to be evacuated on the platform.

c) An average of 0.35 square meters per passenger (Underground) and 0.25 square meters per passenger (Elevated), Level of Service (LOS) 'D' are used under delayed service conditions.

d) The train will not move from the platform until passengers have begun clearing the platform and hence the 600 mm unoccupied zone adjacent to the platform edge is not considered in the calculation of platform width in this scenario.

Space occupied by lifts (elevators), stairs, escalators, structure, platform supervisor's accommodation, etc., shall not be included as part of the platform area.

Thus Required Platform Width = [(3SIxF) + TL] 0.35 / PL or [(3SIxF) + TL] 0.25 / PL for underground and elevated respectively

Where:

SI = Service Interval (minutes)

F = Peak one minute flow of boarding passengers entering onto a platform (i.e. wishing to travel in a given direction)

TL = Full Crush loaded train capacity

PL = platform length

The platform width considered would be higher of the above two service scenario.

Table 4-2 shows the platform width calculation for underground and elevated stations. The assumptions taken for these calculations are 12 coach rakes with a total rake length of 288 m and platform length of 320 m. running at a peak frequency of 5 minutes per train at a crush load of 428 per coach (5136 for one rake). Changes in the system specifications will change the platform widths, the final width would be based on the final figures at the DPR stage.

Table 4-2: Station and Platform Width of RRTS Stations

Station Name	Peak Hour Passenger Load (Maximum of Peak Direction Peak Hour Boarding / Alighting Load)	Calculation of platform width			Platform Width (Considering Two Missed Headways)	Platform Width (Normal Condition)	Viaduct Width (M)	Max. Width Of Ancillary Spaces(M)	Total Station Width (Considering Two Missed Headways)	Total Station Width (Normal Condition)
		Peak 15min . Flow	Peak 5min. Flow	Peak 1 Min. Flow						
ISBT	4593	1240	546	109	5.3	1.5	10	5.4	31	24
NDLS	5776	1560	686	137	5.6	1.7	10	5.4	32	24
NZM	8808	2378	1046	209	6.5	2.2	10	5.4	34	25
INA	6217	1679	739	148	5.7	1.8	10	5.4	32	24
DHAULAKUAN	1325	358	157	31	4.4	0.8	10	5.4	30	22
MAHIPALPUR	9976	2694	1185	237	6.8	2.5	10	5.4	34	26
CYBER CITY	10639	2873	1264	253	7.0	2.6	10	5.4	35	26
IFFCO CHOWK	6365	1719	756	151	6.1	2.0	10	5.4	33	25
RAJIV CHOWK	4487	1211	533	107	5.3	1.4	10	5.4	31	24
MANESAR	8501	2295	1010	202	5.1	2.2	10	5.4	31	25

Station Name	Peak Hour Passenger Load (Maximum of Peak Direction Peak Hour Boarding / Alighting Load)	Calculation of platform width			Platform Width (Considering Two Missed Headways)	Platform Width (Normal Condition)	Viaduct Width (M)	Max. Width Of Ancillary Spaces(M)	Total Station Width (Considering Two Missed Headways)	Total Station Width (Normal Condition)
		Peak 15min . Flow	Peak 5min. Flow	Peak 1 Min. Flow						
PANCHGAON	2979	804	354	71	3.9	1.2	10	5.4	29	23
DHARUHERA	4111	1110	488	98	4.1	1.4	10	5.4	29	24
BTK	8417	2273	1000	200	5.1	2.2	10	5.4	31	25
MBIR	3104	838	369	74	4.0	1.2	10	5.4	29	23
REWARI	12051	3254	1432	286	5.9	2.8	10	5.4	33	26
BAWAL	13883	3748	1649	330	6.3	3.2	10	5.4	33	27
SNB	10938	2953	1299	260	5.6	2.6	10	5.4	32	26
KHAIRTHAL	4071	1099	484	97	4.1	1.4	10	5.4	29	24
ALWAR	7266	1962	863	173	4.8	1.9	10	5.4	30	25

The actual train capacity (including crush load) for RRTS would be much lower than the one used for calculation purpose and hence, station box width would be between 29 m and 35 m. The following section provides brief narrative of all RRTS Stations and typical station Layout. The ridership mentioned is boarding figures for respective stations.

4.5.4 Typical Station Design

A typical station design considers the approximate platform width, length and approximate width and length of service and ancillary unit areas (see table 4-2). Figures 4-8 to 4-15 show the typical station design of underground and elevated stations and cross section of elevated stations. These typical designs are used to locate the station box on the available parcel of land. The actual design for each location based on topographic survey would be developed at the DPR stage.

4.5.5 ISBT RRTS Station

Ridership for the station in 2041 has been projected at 44,340 trips per day. The proposed underground station is below St. Stephen's Ground and is west of the existing DMRC Station. The station would be integrated with the existing ISBT and Metro Station as well as the proposed RRTS – Panipat Line and Proposed DMRC Phase –III station. There would be no TOD design for the station as there is already a redevelopment plan being prepared by DIMTS for ISBT and surrounding areas. The plan will take care of the development around the station. There would be no separate parking for the station. The redevelopment plan for ISBT-Kashmere Gate would consider the parking requirement for all the Modes and feeder services available at ISBT Multi-modal Transportation hub.

4.5.6 New Delhi RRTS Station

Ridership for the station in 2041 has been projected at 54,280) trips per day. The proposed underground station is along Bhav Bhooti Marg (CRPF Camp Land or north of Crowe Chowk), south of the existing Airport Link Station and east of New Delhi Railway Station. The station would be integrated with the existing Railway Station, DMRC Yellow Line Station and Airport Link (DAMEL) Station. However, no development will be aboveground if CRPF land is not acquired. As the RRTS line would cross the DMRC line and the DAMEL, due to the depth of the tunnels there would be major changes in the station design. There would be no provision for separate parking for the RRTS Station.

4.5.7 Sarai Kale Khan (Nizamuddin) RRTS Station

Ridership for the station in 2041 has been projected at 84,950 trips per day. The proposed RRTS station for the Alwar Line will run parallel to the proposed DMRC station and RRTS–Meerut Line. The integration of the three stations at all levels is currently being discussed (this would reduce construction costs). RRTS – Alwar Line will cross DMRC line and the Indian Railway line underground. The depth of DMRC line would have an impact on the station depth and integration with other stations. The arrangement of these stations from west to east would be DMRC station, RRTS – Alwar Station and then RRTS – Meerut Station. Commercial Development has been proposed at the various underground and above ground levels of the station.. There would be no separate parking for the station. The redevelopment plan for ISBT-Sarai Kale Khan would consider the parking requirement for all the Modes and feeder services available at the ISBT Multi-modal Transportation hub.

4.5.8 INA RRTS Station

Ridership for the station in 2041 has been projected at 55,515 (boarding) trips per day. INA RRTS underground station is proposed below the existing DTC Bus Depot. Integration of the station with the existing INA Station of DMRC yellow line as well as with the proposed Phase – III DMRC station would be done. The RRTS line would cross the yellow line from below; hence the station would be designed at considerable depth. The actual design changes and integration along with commercial development at various underground and above ground level would be detailed after consultation with relevant authority. Parking requirement for various modes would be worked out based on the site constraints and land available.

4.5.9 Dhaulakuan RRTS Station

Ridership for the station in 2041 has been projected at 11,565 trips per day. The underground station is proposed south of ARSD College. The station is proposed to be integrated with Dhaulakuan DMRC phase III station and Airport Link. A feeder system is also proposed for the station and surrounding areas of RK Puram, Chanakyapuri and South Campus of Delhi University. Parking for the station would be based on the land availability after topographic survey at the DPR stage.

4.5.10 Mahipalpur RRTS Station

Ridership for the station in 2041 has been projected at 1,45,720 trips per day. Mahipalpur RRTS underground station is proposed west of the existing Mahipalpur settlement and west of NH-8. There would be no development other than station due to AAI (Airports Authority of India) restrictions. In the future, Mahipalpur would be integrated with Aerocity on the DAMEL. No separate parking would be provided for this station.

4.5.11 Cyber City RRTS Station

Ridership for the station in 2041 has been projected at 1,25,675 trips per day. When travelling from Delhi, Cyber City is the first RRTS Station in Haryana State. The planned station is below the green belt along NH-8. Parking for the station would be designed based on the land availability around the station. There would be no property development as the proposed station is close to the NH-8 flyover and high tension wires use the air rights above the stations.

4.5.12 IFFCO Chowk RRTS Station

IFFCO Chowk RRTS is being provided to integrate DMRC yellow line (IFFCO Chowk to Jahangirpuri) and the future extension of Airport Express Link till IFFCO Chowk. The station would be East of NH – 8, south of Westin Hotel and RITES building. The daily ridership at the station for the year 2041 is projected at 67,105 passengers.

4.5.13 Rajiv Chowk RRTS Station

Ridership for the station in 2041 has been projected at 67,145 trips per day. The proposed station is elevated and before the flyover along NH-8 on the eastern side (on the green belt of NH-8, in front of Lafarge Cement Office). No TOD has been planned due to the flyover next to the station site. Parking space for the station would be worked out after the land availability status as per the topographic survey.

4.5.14 Manesar RRTS Station

Manesar RRTS elevated station is proposed along NH-8. Forecast for daily ridership for the year 2041 stands at 96,520. Land for Station and TOD would be acquired along NH-8. Subsequent changes in the Master Plan are also proposed and to be discussed with the stakeholders. The station would provide access to IMT Manesar and existing small settlement around the area. High Density development above and around the station has been proposed. The total land to be acquired for station will be 6.3 hectares. There will be no transit oriented development at Manesar Station. The station is proposed along the NH-8 on the proposed Master Plan Green Belt. If permitted, TOD would be planned above the space acquired for parking and other infrastructure. For details please refer figure 4.16

4.5.15 Panchgaon RRTS Station

Ridership for the station in 2041 has been projected at 44,440 trips per day. Panchgaon Elevated RRTS Station is located before the KMP expressway (currently under construction). The station would be a major interchange point for the NCR and would provide access to upcoming Industries in Gurgaon –Manesar Urban Complex, IMT Manesar and ECC. The total land to be acquired for station and TOD purpose is 29.96 hectares.

Transit Oriented Development Panchgaon RRTS Station

Table 4-3 shows the area to be acquired and area proposed under various uses. The land is currently being used for agricultural and residential purposes. Change of land use is proposed for the area to high density mixed use. Figure 4-17 shows the proposed site Plan for the TOD. Table 4-3 shows the detailed floor area development for the TOD.

Table 4-3: Panchgaon Station and TOD Details

Station	Panchgaon
Area under Transit Oriented Development (Including Station Box) (Ha)	29.96
Parking (no.)	7785
Area Under Commercial (Ha)	23.17
FAR	3.2
Floor Area Under Commercial Office Space (sq.m.)	741440
Floor Area Under Commercial Retail Space (sq.m.)	363306
Area Under Residential (sq.m.)	155702

4.5.16 Dharuhera RRTS Station

Dharuhera RRTS Elevated Station is proposed along one of the Master Plan roads east of NH-8. The proposed land use around the station is industrial, transportation and residential. The land to be acquired for the development of Station and TOD would be approximately 27.02 hectares. Daily ridership projected for the year 2041 is 45,000 trips per day.

Transit Oriented Development Dharuhera RRTS Station

Total land proposed under TOD is 27.02 hectares. Change of land use to High Density mixed use is proposed for the site. The total floor area developed under commercial and residential uses are 668160 sqm. Figure 4-18 shows the proposed site Plan for the TOD. Table 4-4 shows the detailed floor area development for the TOD.

Table 4-4: Dharuhera Station and TOD Details

Station	Dharuhera
Area under Transit Oriented Development including Station Box(Ha)	27.02
Parking (no.)	6891
Area Under Commercial (Ha)	13.09
FAR	3.2
Total Floor Area Proposed Commercial (sq.m.)	418880
Floor Area Under Commercial Office Space (sq.m.)	205251
Floor Area Under Commercial Retail Space (sq.m.)	87965
Area Under Residential (ha)	7.79
Total Floor Area - Residential (sq.m.)	249280

4.5.17 BTK RRTS Station

The proposed elevated station is south of proposed ISBT, north of DFC corridor and east of SH -25. The master Plan proposal for the location is mixed use – high density, which suits the TOD requirements. The land to be acquired for TOD purpose is 120.94 hectares. Daily ridership for the station is 115185.

Transit Oriented Development BTK RRTS Station

Total Land proposed under TOD is 120.94 hectares. Change of land use to High Density mixed use is proposed for the site. The total area under commercial and residential purpose stands at 82 hectares (combined). The total floor area developed under commercial and residential uses is 1702400 sqm. Figure 4-19 shows the proposed site Plan for the TOD. Table 4-5 shows the detailed floor area development for the TOD.

Table 4-5: BTK Station and TOD Details

Station	BTK
Area under Transit Oriented Development (Ha)	120.94
Parking (no.)	27094
Area Under Commercial (Ha)	53.2
FAR	3.2
Total Floor Area - Commercial (sq.m.)	1702400
Floor Area Under Commercial Office Space (sq.m.)	834176
Floor Area Under Commercial Retail Space (sq.m.)	357504
Area Under Residential (ha)	28.81
Total Floor Area Residential (sq.m.)	921920

4.5.18 MBIR RRTS Station

MBIR elevated station is proposed along NH-8 in the Master Plan Area of Rewari -2021. The Station is planned for Manesar-Bawal Investment Region proposed under Delhi-Mumbai Industrial Corridor. The station would cater to 48,050 passengers per day in year 2041. TOD has been proposed around the station, this would require change in land use within the Master Plan of Rewari 2021. The total land to be acquired for station and TOD is 60.39 hectares.

Transit Oriented Development MBIR RRTS Station

The proposed TOD would be of area 60.39 hectares, including station facilities. The TOD is proposed to be one of the high density developments in the MBIR. The total floor area to be developed for various purposes is 12,84,800 sqm. The proposed site plan has been shown in figure 4-20. The detailed area wise use has been shown in table 4-6.

Table 4-6: MBIR Station and TOD Details

Station	MBIR
Area Under Transit Oriented Development Including Station Box (Ha)	60.39
Parking (no.)	13328
Area Under Commercial (Ha)	30.03
FAR	3.2
Total Floor Area - Commercial (sq.m.)	960960
Floor Area Under Commercial Office Space (sq.m.)	470870
Floor Area Under Commercial Retail Space (sq.m.)	201802
Area Under Residential (ha)	10.12
Total Floor Area - Residential (sq.m.)	323840

4.5.19 Rewari RRTS Station

Rewari elevated RRTS Station has been proposed in the south of the existing Rewari town, at Sector -28 Transportation use along the proposed outer ring road. The station along with the sector would be developed as a TOD. The total land to be acquired for station and TOD is 62.86 hectares. The daily ridership for the station is 161165.

Transit Oriented Development Rewari RRTS Station

Land at Sector 28 would be developed as transportation and commercial use. Sector -28 - Multi-modal TOD design requires discussions with the stakeholders for integration of at planning, land acquisition and construction stage. The total area that can be developed is 62.86 hectares. Figure 4-21 shows the site plan for the area and Table 4-7 shows the details of TOD.

Table 4-7: Rewari Station and TOD Details

Station	Rewari
Area under Transit Oriented Development including Station Box (Ha)	62.86
Parking (no.)	6975
Area Under Commercial (Ha)	20.76
FAR	3.2
Total Floor Area - Commercial (sq.m.)	664320
Floor Area Under Commercial Office Space (sq.m.)	325517
Floor Area Under Commercial Retail Space (sq.m.)	139507
Area Under Residential (ha)	22.02
Total Floor Area - Residential (sq.m.)	704640

4.5.20 Bawal RRTS Station

Bawal elevated RRTS Station is proposed at the outer peripheral road of the Master Plan of Bawal Controlled Area. The proposed land use for the location is residential and controlled area for future development. Ridership for the station in the year 2041 has been estimated at 1,67,035. The total land to be acquired for station and TOD is 30.15 hectares. Total floor area of 5,79,520 sq.m. is proposed to be developed for residential and commercial purpose.

Transit Oriented Development Bawal RRTS Station

The proposed TOD would be of area 30.15 hectares, including station facilities. The TOD is proposed to be one of the high density developments like MBIR. The total floor area to be developed for various purposes is 5,79,520 sq.m. The proposed site plan has been shown in figure 4-22. The detailed area wise use has been shown in table 4-8.

Table 4-8: Bawal Station and TOD Details

Station	Bawal
Area under Transit Oriented Development including Station Box (Ha)	30.15
Parking (no.)	3061
Area Under Commercial (Ha)	9.11
FAR	3.2
Total Floor Area Commercial (sq.m.)	291520
Floor Area Under Commercial Office Space (sq.m.)	142845
Floor Area Under Commercial Retail Space (sq.m.)	61219
Area Under Residential (ha)	9.00
Total Floor Area - Residential (sq.m.)	288000

4.5.21 SNB RRTS Station

SNB elevated RRTS Station is proposed east of NH-8 on proposed transportation land use as per the master plan. The proposed land use for the location is transportation for the future development. Ridership for the station in the year 2041 has been estimated at 93,305 per day. The total land to be acquired for station and TOD is 125 hectares. Total floor area of 23,87,520 sq.m. is proposed to be developed for residential and commercial purpose.

Transit Oriented Development SNB RRTS Station

The proposed TOD would be of area 125 hectares, including station facilities. The TOD is proposed to be one of the high density developments. The total floor area proposed to be developed for various purposes are 2387520 sq.m. The proposed site plan has been shown in figure 4-23. The detailed area wise use has been shown in table 4-9.

Table 4-9 : SNB Station and TOD Details

Station	SNB
Area under Transit Oriented Development including Station Box (Ha)	125
Parking (no.)	11810
Area Under Commercial (Ha)	35.15
FAR	3.2
Total Floor Area - Commercial (sq.m.)	1124800
Floor Area Under Commercial Office Space (sq.m.)	551152
Floor Area Under Commercial Retail Space (sq.m.)	236208
Area Under Residential (ha)	39.46
Total Floor Area Residential (sq.m.)	1262720

4.5.22 Khairthal RRTS Station

Khairthal elevated RRTS Station is proposed south of Harsauli Road and south west of Khairthal Master Plan area. The existing land use is agricultural and the proposed land use in controlled area for future development. Ridership for the station in the year 2041 has been estimated at 77,600 per day. The total land to be acquired for station and TOD is 27.92 hectares. Around 91 hectares of land is proposed to be earmarked for recreational hub due to topography and terrain of the surrounding area.

Transit Oriented Development Khairthal RRTS Station

The proposed TOD would be of area 27.92 hectares, including station facilities. Other than this area, there is a proposal to develop a recreational hub. This recreational hub would be development at a later stage a total of 91 hectares has been identified to be acquired at a later stage. Figure 4-24 shows the location, site plan of the TOD and the recreational hub. The total floor area developed for various purposes are 4,98,880 sq.m. The detailed area wise use has been shown in table 4-10.

Table 4-10: Khairthal Station and TOD Details

Station	Khairthal
Area Under Station, Transit Oriented Development and Recreational Hub (Ha)	118.92
Area under Transit Oriented Development including Station Box (Ha)	27.92
Parking (no.)	5238
Area Under Commercial (Ha)	15.59
FAR	3.2
Total Floor Area Commercial (sq.m.)	498880
Floor Area Under Commercial Office Space (sq.m.)	244451
Floor Area Under Commercial Retail Space (sq.m.)	104765

4.5.23 Alwar RRTS Station

Alwar is the last RRTS station from the Delhi side and is one of the most important stations since Alwar is the Regional Center in the Rajasthan sub-region of NCR. Alwar will also have the depot for the RRTS Delhi –Alwar Line. Daily Station ridership for the Alwar Station in 2041 is estimated to be 44,380. The proposed station is south of the existing Alwar-Mathura Line, west of NH-25. The land in the east (till the existing residential development) station is proposed for TOD. A 30 m wide road would provide access to the station from NH-25. An ISBT is proposed in the south of the location and future integration of RRTS station with the ISBT would be done.

Transit Oriented Development – Alwar RRTS Station

Around 28 hectares of land is available around the proposed RRTS Station. The available area is proposed to be used for private, public and IPT modes as well as for commercial, institutional and residential development. Table 4-11 shows the proposed broad land use distribution and parking requirements for the proposed TOD. Figure 4-25 shows the proposed conceptual site plan for the proposed site. The actual land available for development and the detailed site plan and developable area would be know only after the topographic surveys and land available for acquisition. A 30 m wide road is proposed as the main access (NH-25). The site plan would have a hierarchical network of 30, 20 and 10 m ROW roads. To make the development pedestrian friendly a network of footpath has been proposed. The western part of the TOD would comprise mainly of high density residential development to merge with the existing land use pattern. The commercial development would capitalize on the accessibility NH-25 and RRTS Station. Three floors above the platform level are also proposed for commercial development.

Table 4-11: Alwar Station and TOD land Use and other Details

Station	Alwar
Area under Transit Oriented Development including Station Box (Ha)	28.0
Parking (no.)	2547
Area Under Commercial (Ha)	7.58
FAR	3.2
Total Floor Area Commercial (sq.m.)	242560
Floor Area Under Commercial Office Space (sq.m.)	118854
Floor Area Under Commercial Retail Space (sq.m.)	50938
Area Under Residential (ha)	6.42
Total Floor Area - Residential (sq.m.)	205440

5. Train Operation Plan

5.1. Operation Philosophy

The train operation philosophy envisages the following -

- an operating system which efficiently meets the demands of traffic;
- a timetable which ensures punctual running of trains at reasonable comfort levels;
- ensuring safety of operations;
- optimizing the usage of rolling stock; and
- Incorporating multi-skilling of staff for operations (Station Controllers /Drivers and customer care staff etc).

5.2. Station yard planning

5.2.1 Station Yard Design

The design for station Yard should take care of -

- Flexibility in Operation;
- Emergency provisioning of Crossovers; and
- Stabling facilities at some of the stations.

5.2.2 Number of Stations

The total numbers of stations on the specified corridor are 19. Of these, two are terminals, one at each end of the corridor i.e. ISBT (Kashmere Gate) and Alwar. The other 17 stations are intermediate stations. The following table provides the names of the stations and approximate inter station distances.

Table 5-1: Inter station Details

Sl. No	Station Name	Inter-station Distance (KM)	Distance (Cumulative)
1.	ISBT (Kashmere Gate)		00
2.	New Delhi RS	3.50	3.50
3.	Sarai Kale Khan (NZM)	7.00	10.50
4.	INA	5.00	15.50
5.	Dhaula Kuan	4.50	20.00
6.	Mahipalpur	6.50	26.50
7.	Cyber City	7.50	34.00
8.	IFFCO Chowk	3.20	37.20
9.	Rajiv Chowk (G)	3.80	41.00
10.	Manesar	13.50	54.50
11.	Panchgaon	9.50	64.00
12.	Dharuhera	13.00	77.00
13.	BTK	9.00	86.00
14.	MBIR	15.00	101.00
15.	Rewari	5.50	106.50
16.	Bawal	12.50	119.00
17.	SNB	7.00	126.00
18.	Khairthal	29.50	155.50
19.	Alwar	24.50	180.00

5.2.3 The Intermediate stations can be provided with either directional platforms or island platforms.

The advantages of an island platform are:

(i) Easy transfer from one route to another;

(ii) Reduced maintenance cost;

(iii) Provision of common services on the platform; and

(iv) Easy passenger accessibility.

5.2.4 The specified corridor does not involve any change of route. Hence, the first advantage is only academic.

5.2.5 The disadvantage of an island platform is the possibility of overcrowding, if trains get delayed due to whatever reasons and inability to segregate arrival and departure streams. Segregation also implies opening of doors on either side separately and, therefore increased dwell time. It can lead to a stampede if crowd becomes unmanageable. In case of unforeseen delays or surges if the platform gets overcrowded, it will become necessary to control the ingress of both the streams. In a directional platform the traffic of only one direction would have to be controlled. However, island platform can be considered for stations with low level of traffic. Traffic figures for 2041 indicate comparatively poor patronage at the following stations.

Table 5-2: Stations with low traffic (2041) patronage

Station Name	Total No. of Passengers
Dhaula Kuan	11565
Panchgaon	44440
Khairthal	39285

Further, the peak hour boarding / alighting for these stations for 2041 are indicated below:

Table 5-3: ISBT Kashmere Gate- Alwar

Station Name	Boarding	Alighting
Dhaula Kuan	1325	0
Panch Gaon	1371	2339
Khairthal	377	2763

Table 5-4: Alwar –ISBT Kashmere Gate

Station Name	Boarding	Alighting
Dhaula Kuan	0	988
Panch Gaon	2199	2979
Khairthal	4071	646

5.2.6 Based on the level of traffic an island platform could be recommended for Dhaula Kuan station. However, the traffic forecasting was done on the basis that short distance traffic may not be allowed. Boarding and alighting figures of Dhaula Kuan are low because of this embargo. As this may not be enforceable in the conditions prevailing in the country; hence, island platform may not be suitable for this station also, and directional platforms are proposed.

All other stations excepting the terminal stations will, therefore, have directional platforms. A schematic diagram of such an arrangement is given in Figure 5-1.

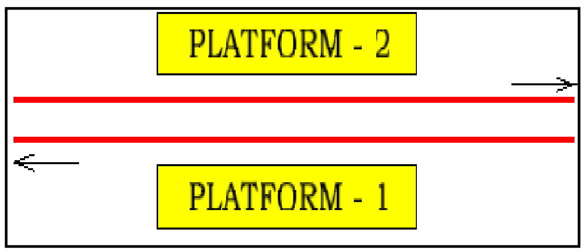


Figure 5-1: Directional platform arrangement

5.2.7 The terminal stations, however, can have two types of arrangements. One arrangement will provide a track between the platforms on either side. This arrangement can be used for segregating the arrival and departure streams. This will also necessitate the opening of the doors on one side for egress and opening of the doors on the other side for ingress after alighting is completed. Such an arrangement exists at Church Gate Station but without segregation. The disadvantage in such an arrangement is that the people may, in all likelihood, start getting in before the evacuation has taken place any way. In fact segregation, though theoretically possible, may not be enforceable. The other disadvantage would be that the safe to run examination of the rakes which may have to be done during the night hours when the services are not scheduled to run i.e. odd hours to 5 a.m. will not be possible. Yet another disadvantage would be that the stabling facilities would be limited in this arrangement as the lines will physically terminate abutting the platform and cannot be extended further.

Prima facie, land availability in Delhi area for a depot is limited. Even if a depot is located in Delhi area the train operation may require some stabling lines at ISBT (Kashmere Gate) terminal to achieve the desired frequency of 5 minutes in 2041. The terminal at Alwar will also have to be provided with directional platforms as future planning should provide scope for extending the Rapid Transit System to Jaipur if considered feasible later.

5.2.8 The achievement of a 5-minute frequency would require a total flexibility of operations. This implies that it should be possible to receive and dispatch all trains from the terminal and ideally at all intermediate stations from any of the platforms. This would be possible if scissors crossover arrangement is laid or two separate crossovers are laid. Schematic diagrams of scissors cross-over and separate cross over are given below:

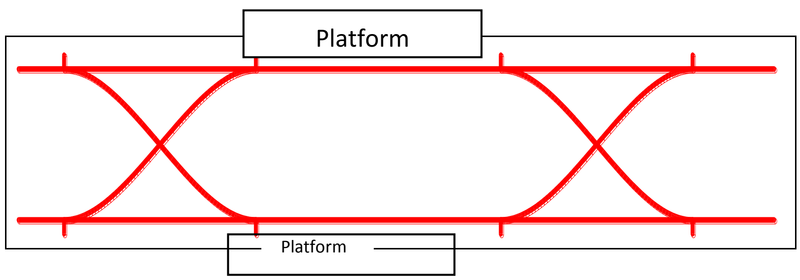


Figure 5-2: Scissors cross over

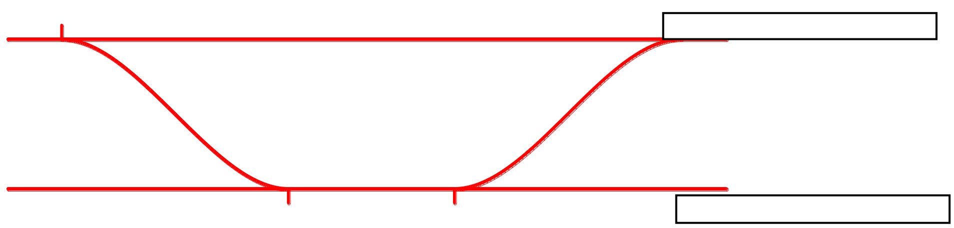


Figure 5-3: Separate cross over

5.2.9 The advantage of Scissors crossover would be saving of space. This would occupy approximately 100 meters of track space. If two separate crossovers are provided the space required would be double i.e. 200 meters. Scissor crossovers will be provided at Stations where common loop/stabling sidings are not planned and where emergency crossovers also do not exist. As these crossovers enhance the flexibility of operations; this will be provided at all important junctions and terminals. These crossovers would be provided at ISBT, New Delhi, Nizamuddin, BTK, Rewari and Alwar.

5.2.10 New Delhi terminal would become an intermediate station as the line would be extended to ISBT (Kashmere Gate) where the main terminal would be developed. However, it would be the most important station on the route and would be the central hub providing connectivity to the main I.R network, local bus services and the metro systems. Hence, the platforms would have to be of spacious design to accommodate the influx and exodus of passengers. The width of the platform and the concourse would have to be custom designed for passenger convenience. In view of this station being important hub on the corridor, it will have to be provided with a scissors crossover on one side to achieve full flexibility.

5.2.11 ISBT (Kashmere Gate) would be the terminal of RRTS Corridor. It would require stabling facilities which would be determined by the availability of space. Two options can be envisaged. One option would be of a depot at Sarai Kale Khan or in its proximity. This would enable empty rakes being made available for services at ISBT in 8 minutes. In this case the depot would have to be provided with stabling facilities for 15 rakes in 2041. The other major depot will be established near MBIR/ Rewari. The journey time from MBIR/Rewari would be about an hour. In this option some stabling facilities would have to be developed at ISBT (Kashmere Gate) and Nizammudin (Sarai Kale Khan).

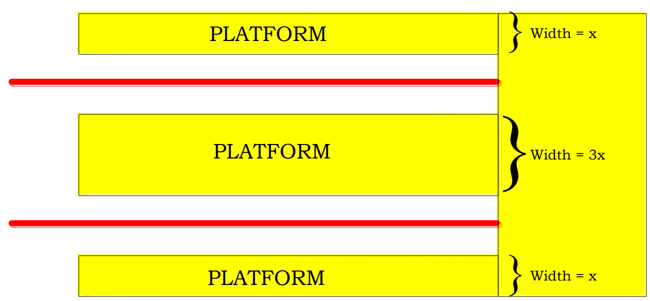


Figure 5-4: Platform Configuration

In case a depot is established near Sarai Kale Khan then it is possible to provide platforms on both the sides for passenger’s convenience and comfort at ISBT. A schematic diagram is given at right:

(a) In the above arrangements the only way in which stabling facilities can be developed is to provide one line beyond platform and one line in between the main lines. This is shown in the Figure 5-5 below:

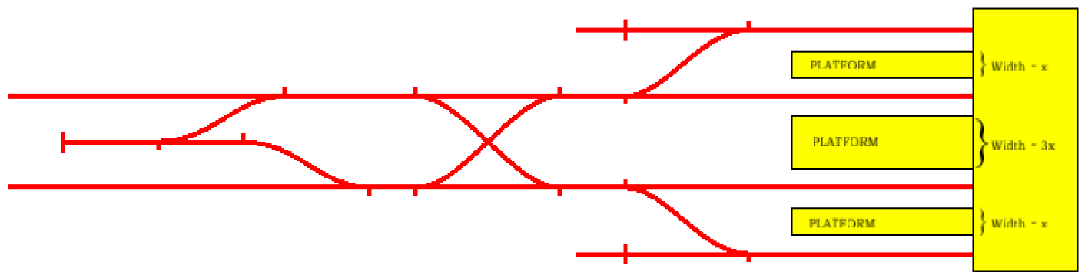


Figure 5-5: Stabling Facility

It would be possible to hold 3 rakes (assuming the length of the line to be at least 450 meters) on each of the stabling lines i.e. 3x3, 9 rakes of 6 coaches each. This would enable the services to be run for one hour (2041). If it is not possible to find a place in Sarai Kale Khan, then this arrangement cannot be envisaged. In that case a balloon shaped yard would have to be made to permit stabling and train examination. A schematic diagram is shown in Figure 5-6 below:

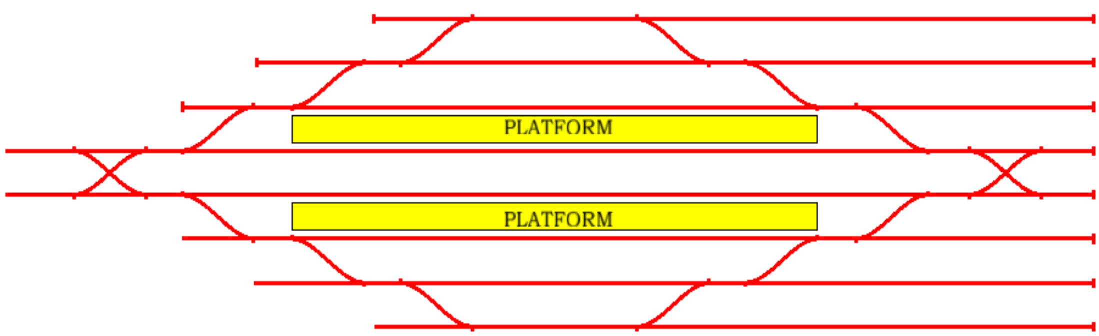


Figure 5-6: Train Yard

The terminal at Alwar will have a separate configuration because of the establishment of the depot at that place. Since the depot would require a stabling yard of sufficient capacity no extra stabling lines would be required at this station. However, here also the arrangement of platform on both sides of one track cannot be recommended keeping the possibility of future extension of this corridor to Jaipur in view.

5.2.12 Considering the intensity of train operations even with advanced signalling and automatic systems, provision will have to be made for emergency crossovers (EC) in the reverse direction at selected intermediate stations. Such crossovers will be provided at stations as listed below.

Table 5-5: Location of Crossover Facility

S. No	Station Name	Distance from ISBT (Kashmere Gate) (Km)	Distance between stations with emergency crossovers (Km)
1.	Mahipalpur	26.50	
2.	Rajiv Chowk	41.00	15.50

5.2.13 The reason why the emergency crossovers have been provided at only two stations is because of the necessity to provide scissors crossovers or two crossovers on either side at other stations. The emergency crossovers have been provided at Stations, where scissors/other crossovers are not provided.

5.2.14 Notwithstanding all the precautions and the technological advancement, the possibility of trains getting disabled while on run cannot be ruled out. In such cases, it will be necessary to bring the disabled train which would be occupied by passengers to the next station for their evacuation. In order to provide space for holding such disabled train and to minimize the deleterious effect of operations two methods could be conceived. Firstly, a dead ended spur could be made at selected stations where the disabled train could be placed before it is taken to the depot at an appropriate time. (e.g. if the disabling takes place during the peak period in order to carry the traffic smoothly, it will have to be parked for a few hours and subsequently moved during non peak hours). The other method would be to provide a common loop where the disabled train could be left alongside the platform. A schematic diagram of the two methods discussed is given in figure 5-7.

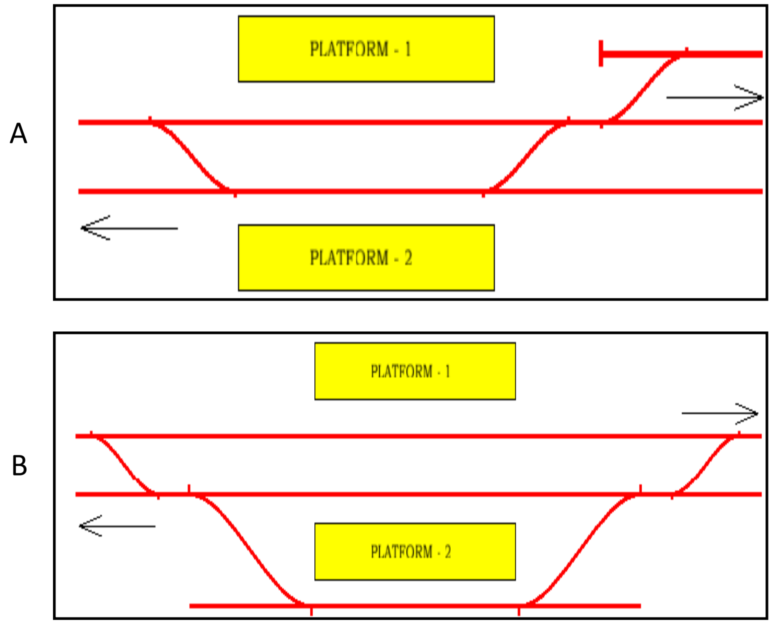


Figure 5-7: Method A & B

The advantages of the Second method (B) in enhancing the operational flexibility are manifold. These are listed below:

(a) Stabling disabled rake for being sent to the Depot on an operationally convenient time.

(b) In case main line track of UP or DN direction becomes faulty in station areas, operational flexibility will enable handling of trains from either direction.

(c) If for any other reason, trains develop a glitch on the main line platform traffic can be passed via the loop.

(d) Rates can be withdrawn from revenue services during non peak hours, stabled and subsequently made available as per operational requirement.

(e) Elimination of shunting time for taking the rake in the spur/dead ended siding both for placement and withdrawal.

(f) Elimination of detention to trains from any direction during the peak services for want of platform availability. However, it may be stated that such detentions will be rare.

(g) In emergency, trains can be originated/ terminated.

It may, however, be clarified that in the proposed RRTS System, no precedence are envisaged as all trains run at the same speed and there is no justification of fast and slow services.

The cost difference in these two alternatives appears to be negligible because only one extra crossover is required in the provision of a common loop. The underground section extends from ISBT to IFFCO Chowk for a distance of about 39 Km. It will be essential to provide one stabling/common loop facility in the underground section. Operationally, such a loop should be provided at Dhaula Kuan, at a distance of 20 KM from ISBT and 18 KM from IFFCO Chowk. The other alternative could be to provide such a facility at INA but that would be too close to Sarai Kale khan (Nizamuddin) where it is proposed to develop a maintenance facility. Such common loops will be provided at the following stations:

Table 5-6: Location of Maintenance Loops

S. No.	Name of the Station	Distance from ISBT	Direction of the loop
1.	Dhaula Kuan	20 KM	UP
2.	Rajiv Chowk	41.0 KM	DN
3.	Manesar	54.5 KM	UP
4.	Dharuhera	77 km	DN
5.	MBIR	101 KM	UP
6.	SNB	126 KM	DN
7.	Khairtal	155.5 KM	DN

5.3. Train Operation Plan

The Train composition involves selection of (a) coaches and (b) their number.

5.3.1 Safety Features.

The system of operation is based on continuous automatic train protection to ensure foolproof safety of the highest level eliminating the need for human intervention as far as possible. In case of any emergency, proper evacuation plan for passengers will be designed in the Rules of Operation.

Rolling stock is designed with retardant materials. The couplers are designed to reduce the impact of accidents with crash worthiness features.

5.3.2 Coach Capacity:

A study of the world wide metro systems indicates that the coach capacity is determined on various loading conditions as indicated below:

(i) Normal Load: Seated + standees @ 4 persons per sq. meter.

(ii) Crush Load: Seated+ standees @ 6 persons per sq. meter; and

(iii) Dense Crush Load: Seated + standees @ 8 persons per sq. meter.

Seating capacity is limited to 15 to 20% of the coach capacity and the seating arrangements are longitudinally placed for quicker entrainment/detrainment. The coaches themselves are of three types i.e. driving trailer Coach (DTC); Trailer Coach (TC) and Non-driving Motor Coach (MC). The following chart indicates the seated and standees capacities under various conditions for DMRC coaches:

Table 5-7: Coach Capacities

S. No.	Loading Condition	Capacity of MC/TC			Capacity of DTC		
		Seats	Standing	Total	Seats	Standing	Total
1.	Normal Load	50	124	174	42	120	162
2.	Crush Load	50	248	298	42	240	282
3.	Dense Crush Load	50	330	380	42	319	361

5.3.3 DMRC has two types of coaches depending upon the gauge. The broad gauge coaches have a capacity of 50 seating and 248 standees (6 persons per sq. m.), and the standard gauge coaches with a normal width of 2.9 meters have a capacity of 50 seating and 220 standing passengers and for 3.2 meters wide coaches a capacity of 50 seated and 248 standees.

5.3.4 Consideration has been given to the fact as to whether standing passengers should be allowed or not. A study of the various mass transit systems in different countries indicates the following picture.

Table 5-8: Features of relevant Transit systems

S. No.	Name of City	No. of Coaches in a train	Coach Cap.	Standees Allowed or not
1.	Toronto	6	120	Allowed
2.	New York	6	50-60	-do-
3.	San Francisco	6-8	62-72	-do-
4.	Paris	4-12	220	-do-
5.	London	4	175	-do-
6.	Zurich	8	212/66	-do-
7.	Kuala Lumpur	4	32	-do-

It is observed that standing is allowed in all these systems. This has further been related to the speeds in view of the difference between the MRTS and RRTS systems even though both cater to mass transit. The following table indicates the speeds.

Table 5-9: Speeds of Similar systems

S. No.	System	Max. Speed (in km)	Av. Speed (in km)
1.	Toronto	120	60
2.	New York	120	60
3.	San Francisco	130	53
4.	Paris	140	60
5.	London	160	70
6.	Munich	146	50
7.	Kuala Lumpur	160	80

It will be seen that with a maximum speed of 160 KMPH standing has been allowed without exception.

5.3.5 An effort has been made to further study the impact on the standing passengers at the speeds proposed for the RRTS system i.e. 160 KMPH. It is found that the standing passengers with supports can easily travel in reasonable comfort as human body can withstand the maximum acceleration of 3 meters per second per second. [2]The observation indicated above confirms the conclusion of standing being allowed in rapid rail facilities.

5.3.6 As a precautionary measure, to enhance the comfort levels of the travelling public, the coach capacity of 226 persons per coach including standing has been decided. This will comprise 100 seating and 126 standees with a transverse seating arrangement of 3+2 in each row.

5.4. Train Frequency

5.4.1 The train frequency is related to Peak Hour Peak Direction Traffic/ Peak Sectional Load in various horizon years.

5.4.2 The train frequency for the above scenario has been calculated as follows.

Table 5-10: Train Frequency (ISBT Kashmere Gate- Alwar)

Year 2016				
		No. of Coaches	Coach Cap/ Train Cap	(Frequency)
PHPDT	13800	6	226x6=1356	6.0
Year 2021				
PHPDT	15,700	6	226x6=1356	5.0
Year 2031				
PHPDT	21,800	9	226x9= 2034	6.0
Year 2041				
PHPDT	25,800	9	226x9=2034	5.0

5.4.3 It is gleaned from the above Table that in 2031, 9 coach trains with 226 persons per coach would have to be run at headway of 6.0 minutes to meet the demand of traffic. A 6 coach rake would not do. Similarly for 2041, 9 coach rakes at 5.0 minutes headway will have to be pressed in service.

[2] *source: M.S. Griffin – Handbook of Human Vibrations*

5.4.4 As an abundant precaution and adopting a visionary planning approach, the maximum number of coaches in a train for ISBT-Alwar Corridor has been pegged at 12 coaches. This will determine the platform length so that the system does not need any alteration even beyond 2041. Ample capacity would exist to meet all the surges in traffic demand in future. These coaches would be 24.0 meters long and 3.66 meters wide stainless steel light weight coaches with vestibules and would be equipped with air conditioning.

5.4.5 The coaches will have 3 doors (1.4m wide) on either side for facilitating quick evacuation and entrainment. This is necessary as the time-tabling provides a stoppage of half a minute only at each of the stations on the way.

5.4.6 As an added feature, it is pertinent to indicate that coach capacity of 226 persons, which would meet the requirement in 2041 with headway of 5.0 minutes, if increased, would lower the overall cost on the rolling stock, but with constrained level of service and reduced comfort levels.

5.4.7 Train Configuration:

The configuration for a 6 coach train would be as follows:

DMC+TC+MC+MC+TC+DMC

The configuration for a 9 coach train would be as follows:

DMC+TC+MC+MC+TC+MC+MC+TC+DMC

5.5. Time Tabling:

5.5.1 Time-tabling is dependent on the operating speed, booked speed, acceleration, deceleration, and the dwell time at the stations.

5.5.2 It has been decided that the operating speed for the system would be 160 KMPH. Indian Railways maintain a difference of 10% between the maximum and the booked speed to provide a cushion for delays due to unforeseen circumstances to enable the driver to make up time. The system being conceived for this corridor would be fully automatic with minimal human intervention. It would be equipped with cab signalling, automatic train protection, automatic train control and automatic train operation as is provided on the Delhi Metro. Thus, it is not necessary to provide for a 10% cushion between the maximum and the booked speed. However, taking a conservative view it has been decided to provide a margin of 5% between the maximum and the booked speed. This would mean running the trains at 152 KMPH. The booked speed has been rounded off to 150 KMPH.

5.5.3 In view of the difficulties likely to be encountered because of sharp curvatures and short inter-station distances in Delhi area, and to keep the tunnel diameter to a reasonable size, the operating speed in the underground section up to IFFCO Chowk has been pegged at 100 KMPH. This means that the trains will run from ISBT (Kashmere Gate) to IFFCO Chowk (38 Kms) at 100 KMPH and for the remaining portion at 160 KMPH. As the speed in NCT Delhi area will be reduced, the 5% cushion discussed above has been discarded for the residual journey.

5.5.4 As all the trains will run at the same speed, only the timing of one train is given below and the same will be applicable to all other trains which will follow at the desired frequency. These timings are tentative and incorporate time loss due to speed restrictions on curves and recovery time based on approximations as available now.

Table 5-11: Time Table ISBT Kashmere Gate to Alwar

S. No	Station Name	Inter-Station Distance (KM)	Cumulative Distance (Km)	Arrival Time	Departure Time	Time taken (Mt)	Cumulative time (Mt)	Remark
1	ISBT *(Kashmere Gate)			0	06.00		00	
2	New Delhi RS	3.50	3.50	06.03.30	06.04.00	3.30	03.30	1’ TR
3	Sarai Kale Khan (NZM)*	7.00	10.50	06.09.00	06.09.30	5.00	09.00	
4	INA	5.00	15.50	06.13.00	06.13.30	3.30	13.00	

S. No	Station Name	Inter-Station Distance (KM)	Cumulative Distance (Km)	Arrival Time	Departure Time	Time taken (Mt)	Cumulative time (Mt)	Remark
5	Dhaula Kuan	4.50	20.00	06.16.30	06.17.00	3.00	16.30	
6	Mahipalpur	6.50	26.50	06.21.30	06.22.00	4.30	21.30	
7	Cyber City	7.50	34.00	06.29.00	06.29.30	7.00	29.00	2’ TR
8	Rajiv Chowk (G)	7.50	41.50	06.33.30	06.34.00	4.00	33.30	
9	Manesar	13.00	54.50	06.41.00	06.41.30	7.00	41.00	1’ ER
10	Panchgaon	9.50	64.00	06.49.00	06.49.30	7.30	49.00	3’ ER
11	Dharuhera	13.00	77.00	06.56.00	06.56.30	6.30	56.00	.5’ ER
12	BTK	9.00	86.00	07.02.00	07.02.30	5.30	62.00	1’ TR
13	MBIR	15.00	101.00	07.09.30	07.10.00	7.00	69.30	
14	Rewari	5.50	106.50	07.15.00	07.15.30	5.00	75.00	2’ TR
15	Bawal	12.50	119.00	07.23.30	07.24.00	8.00	83.30	2.5’ ER
16	SNB	7.00	126.00	07.30.30	07.31.00	6.30	90.30	1.5’ ER 1’ TR
17	Khairthal	29.50	155.50	07.43.00	07.43.30	12.00	103.30	
18	Alwar	24.50	180.00	07.57.00		13.30	117.00	1’ ER 2’ TR

Traffic Recovery (TR) =9.0minutes; Engineering Recovery (ER) = 9.5 minutes

The timings of a Train in the reverse direction from Alwar to ISBT (Kashmere Gate) are given below:

Table 5-12: Time Table Alwar to Kashmere Gate

S. No	Station Name	Inter-station Distance (KM)	Cumulative Distance (Km)	Arrival Time	Departure Time	Time Taken in (Mt)	Cumulative time (Mt)	Remarks
1	Alwar		00		06.00	00	00	
2	Khairthal	24.50	24.50	06.11	06.11.30	11.00	11.00	1’ ER
3	SNB	29.50	54.00	06.26.00	06.26.30	14.30	26.00	2’ TR
4	Bawal	07.00	61.00	06.31.30	06.32.00	05.00	31.30	1.5’ER
5	Rewari	12.50	73.50	06.42.30	06.43.00	10.30	42.30	2.5’ER
6	MBIR	05.50`	79.00	06.46.00	06.46.30	03.00	46.00	2’ TR

S. No	Station Name	Inter-station Distance (KM)	Cumulative Distance (Km)	Arrival Time	Departure Time	Time Taken in (Mt)	Cumulative time (Mt)	Remarks
7	BTK	15.00	94.00	06.55.00	06.55.30	08.30	55.00	2’ TR
8	Dharu Hera	09.00	103.00	07.00.30	07.01.00	05.00	60.30	00.5´ER
9	Panchgaon	13.00	116.00	07.07.00	07.07.30	06.00	67.00	
10	Manesar	09.50	125.50	07.15.00	07.15.30	07.30	75.00	3’ ER
11	Rajiv Chowk (G)	13.00	138.50	07.23.00	07.23.30	07.30	83.00	1’ ER
12	Cyber city	07.50	146.00	07.29.30	07.30.00	06.00	89.30	2’ TR
13	Mahipalpur	07.50	153.50	07.34.00	07.34.30	04.00	94.00	
14	Dhaula Kuan	06.50	160.00	07.38.30	07.39.00	04.00	98.30.	
15	INA	04.50	164.50	07.42.00	07.42.30	03.00	102.00	
16	Sarai Kale Khan (NZM)	05.00	169.50	07.46.00	07.46.30	03.30	106.00	
17	New Delhi RS	07.00	176.50	07.52.30	07.53.00	06.00	112.30	2’ TR
18	ISBT (Kashmere Gate)	03.50	180.00	07.57.00		04.00	117.00	

ER=9.5 minutes; TR= 10 minutes

5.5.5. The hourly variation of the number of trains in various horizon years has been calculated in the following tables.

Hourly Train Operation Plan (2016)

ISBT (Kashmere Gate) – Alwar Section

Frequency = 6.0 minutes; No. of Coaches = 6

(Coach Capacity = 226 passengers)

Table 5-13: Train Operation Plan 2016

Time	Headway (In Minutes)	No. of Trains (Daily)	
		Up Trains	Down Trains
06-07	30	2	2
07-08	10	6	6
08-09	6	10	10
09-10	6	10	10
10-11	6	10	10
11-12	6	10	10
12-13	15	4	4
13-14	15	4	4
14-15	15	4	4
15-16	15	4	4
16-17	6	10	10
17-18	6	10	10
18-19	6	10	10
19-20	6	10	10
20-21	15	4	4
21-22	15	4	4
Total		112	112

Hourly Train Operation Plan (2021)

ISBT (Kashmere Gate) – Alwar Section

Frequency = 5 minutes; No. of Coaches = 6

(Coach Capacity = 226 passengers)

Table 5-14: Train Operation Plan 2021

Time	Headway (In Minutes)	No. of Trains (Daily)	
		Up Trains	Down Trains
06-07	20	4	4
07-08	8	7	7
08-09	5	12	12
09-10	5	12	12
10-11	5	12	12
11-12	5	12	12
12-13	12	5	5
13-14	12	5	5
14-15	12	5	5
15-16	12	5	5
16-17	5	12	12
17-18	5	12	12
18-19	5	12	12
19-20	5	12	12
20-21	15	4	4
21-22	15	4	4
Total		134	134

Hourly Train Operation Plan (2031)

ISBT (Kashmere Gate) – Alwar Section

Frequency = 6 minutes; No. of Coaches = 9

(Coach Capacity = 226 passengers)

Table 5-15: Train Operation Plan 2031

Time	Headway (In Minutes)	No. of Trains (Daily)	
		Up Trains	Down Trains
06-07	30	2	2
07-08	10	6	6
08-09	6	10	10
09-10	6	10	10
10-11	6	10	10
11-12	6	10	10
12-13	15	4	4
13-14	15	4	4
14-15	15	4	4
15-16	15	4	4
16-17	6	10	10
17-18	6	10	10
18-19	6	10	10
19-20	6	10	10
20-21	15	4	4
21-22	15	4	4
Total		112	112

Hourly Train Operation Plan (2041)

ISBT (Kashmere Gate) – Alwar Section

Frequency = 5.0 minutes;

No. of Coaches = 9

Table 5-16: Train Operation Plan 2041

Time	Headway(In Minutes)	No. of Trains (Daily)	
		Up Trains	Down Trains
06-07	20	3	3
07-08	8	7	7
08-09	5	12	12
09-10	5	12	12
10-11	5	12	12
11-12	5	12	12
12-13	12	5	5
13-14	12	5	5
14-15	12	5	5
15-16	12	5	5
16-17	5	12	12
17-18	5	12	12
18-19	5	12	12
19-20	5	12	12
20-21	15	4	4
21-22	15	4	4
Total		134	134

5.6. Rolling Stock Requirements:

5.6.1 Rolling Stock Requirement is a function of the turn round time and the headway. Considering this headway it would be advisable to run 9 coach trains in 2041 at a frequency of 5.0 minutes which would provide an efficient and manageable service.

5.6.2 The turn round of a rake from ISBT (Kashmere Gate) to Alwar has been calculated at the speeds decided for the system i.e. 100 KMPH for underground and 160 Km over ground. The details of the turn round are given below:

Trip time from ISBT (Kashmere Gate) to Alwar	117 Min
Round trip time	234 Min
Stoppage at ISBT (Kashmere Gate) - Alwar stations	6min (3min each)
Total turn round time	240 Min

It may be clarified that at the terminal stations i.e. ISBT (Kashmere Gate) and Alwar, 3 minutes stoppage time has been given to facilitate the change of driver at the platform. An additional driver would be available near the motor driving coach to take over as soon as the train arrives and then the driver will keep on rotating till the dispatch of the last train.

5.6.3 The following table indicates the requirement of rakes/coaches for various horizon years.

Table 5-17: Rolling Stock Requirement for Various Horizons with different Coach Capacities

Year	PHPDT	No. of Coaches	Coach Capacity/ Rake capacity)	Frequency (Mt)	Turn Round Time (Mt)	No. of Rakes Reqd.	No. of Coaches Reqd.	10% extra For POH *	Total No. of Coaches Required
2016	13800	6	226/1356	6.0	240	40	240	24	264
2021	15700	6	226/1356	5.0	240	48	288	30	318
2031	21800	9	226/2034	6.0	240	40	360	36	396
2041	25800	9	226/2034	5.0	240	48	432	45	477

*Note: * Commensurate with rake composition.*

5.7. Stabling:

The stabling was briefly discussed in paragraph 5.2.11. The rolling stock requirements have already been calculated for various horizon years and are incorporated in Table No. 5-17. It would be imperative to develop stabling facilities in Delhi area to meet the traffic requirement. Operationally it is convenient to provide several depots, from where the rakes can be put in service within a reasonable time of 10-12 minutes. This would be possible if a depot is developed at Sarai Kale Khan (NZM) which is under consideration and will depend upon the space available. If this becomes possible, no stabling facilities will be required at ISBT Terminal. However, if space constraints do not permit creation of such a depot at NZM, stabling facilities would be required at the terminal and in the main depot MBIR/Rewari and the subsidiary depot at Alwar.

The Operational requirements would be met by development of the following stabling facilities:

Table 5-18: Train Stabling Facility

Location	Year	Stabling Lines	Year	Stabling lines
Delhi Area (NZM)	2041	15	2016	12
MBIR/Rewari	2041	30	2016	20
Alwar	2041	15	2016	20
Total		60		52

5.7.1 It may be indicated that in 2016 the train composition would be of 6 coaches. As the stabling lines would be of sufficient length to accommodate 12 car rakes in 2041, it would be possible to stable 2 rakes of 6 coaches each in 2016 in one line. In this context the number of stabling lines in 2016 would get reduced accordingly.

5.7.2 It may be clarified that final figures for stabling would be governed by the location of Depot in Delhi area. In case, there is no space available, stabling lines will have to be created at ISBT/New Delhi/NZM to minimize the empty haulage of rakes and additional lines would be required at the other depots. In case Delhi area cannot be provided with additional 5 stabling lines, MBIR/Rewari will have to be provided with 40 stabling lines.

5.7.3 Multi-skilling of staff enhances the flexibility of operations. This is an innovative practise being adopted by DMRC. The station control staff at interlocked stations is qualified to take over as train operator in any emergency or an abnormal situation. This implies that all station controllers are trained to work as train operators and are issued a competency certificate accordingly

5.7.4 The customer care staff is commercial staff normally not engaged in train operations. Their promotion channel is for station controller, once they are so promoted, they join the main stream of those who are qualified for train operations.

6. Signalling, Telecommunication and Fare Collection

6.1. Signalling and Train Control

6.1.1 Introduction

Any rail based transit system involves heavy capital investment in terms of the right of way and station infrastructure, with significant life cycle costs to maintain the infrastructure in a state of good repair. This investment is justified on the basis that the infrastructure provides the foundation for the movement of large numbers of passengers within the network covered by the transit corridor . The actual safe movement of passengers is however only possible through the implementation of a signalling / train control system, with least human intervention. In reality, it is the signalling / train control system that enables the return on the infrastructure investment to be realized.

While the signalling / train control system is the enabler of Railway operation, the system can also impose a constraint on operations, for example by restricting the achievable line capacity or by limiting the flexibility of train movements .Any train control system should not only provide safety but also maximum flexibility and availability.

Keeping the above in view, Continuous Automatic Train Control (CATC) is proposed. Signalling and train control will conform to international standards like GENELEC, IEC, BS, ITU-T etc.,

6.1.2 Train operation in RRTS:

Train operation in RRTS is characterized by:

- All trains operate at similar speed.
- Precedence are normally rare since speeds are same
- Precedence takes place at stations with crossovers in case of failure of rolling stock or any unusual occurrence
- 25 KV ac traction is proposed to be used
- Powered by Electrical Multiple Units

- The stations are proposed at distance varying from 3.0 km to 7.5 km on underground section and 5.5 km to 29.5 km on elevated section.
- Maximum operational speed 160 kmph.
- Bidirectional signalling
- Trains are controlled by Continuous Automatic Train Control System (CATC)
- The track is an elevated section for 141 km and underground section for remaining 39 km and hence no level crossings.
- Station signals where present are operated centrally from OCC (Operations Control Centre) or locally through computer based interlocking when control is passed to the station by OCC
- Planning and control of train movements are carried out from OCC. The position of trains on the territory are displayed through appropriate display panels at the OCC to enable the controllers to have a real time birds eye view of the main traffic position.
- Extensive IT use is envisaged in different aspects of Railway operation, maintenance, traction power control, MIS etc.
- Planned Headway is within 5 minutes during peak periods in horizon year 2041 .

6.1.3 Why Continuous Automatic Train Control – Limitations of conventional signalling:

The conventional signalling systems does not indicate to the driver the speed to go, the distance to go, exact location of the train, gradient of the track ahead, position of door opening / closing of coach. Further the conventional system solely depends on visibility of signals which again depends on curvature, weather conditions etc. It is pertinent to mention here that the fog problems in the Delhi – Alwar section can disrupt traffic if conventional signalling is adopted. The conventional signalling system has no control on drivers' mistake and hence usually higher margins in speed, distance between two trains are kept. This will result in non-optimum utilization of assets, lesser safety and poorer headway.

To overcome the above restrictions CATC is recommended and has been proposed for signalling and Train Control in the RRTS. The essential functions of CATC are:

- Automatic route setting, automatic train separation (similar to station master, duty)
- Cab signalling i.e, displaying signal aspects in the cab which otherwise will be displayed through way side signals.

- Indicates permitted speed
- Auto start, over speed protection, automatic stop, automatic coasting, stops the train if door opens and over speed alarm. (similar to drivers duty).
- Passenger safety by door opening / closing, emergency stop (similar to guards duty).
- Traffic regulations, time table generation (similar to control office duty)
- Passenger information display (similar to commercial job)
- Maintenance monitoring, crew performance monitoring (managerial job).
- Power operation of points and hand operation of points in case of power failure.
- Computer based interlocking for operation of points and setting of routes to prevent misdirection of trains at points.
- Appropriate vehicle detention system and transmission of data from track to train and vice versa.
- Remote control of interlocking and the indication of equipment status and train location to control centre.
- Authority to proceed along a route set and locked for each train.
- Automatic routine operation including automatic reversals at terminals.
- Provide the designed headway.
- Provide bi-directional working between interlocked stations with crossovers.

6.1.4 CATC System and its sub-systems:

To provide the above functions the CATC system will mainly consist of the following sub-systems:

- Automatic Train Protection (ATP)
- Automatic Train Operation (ATO)
- Automatic Train Supervision (ATS)

6.1.5 Automatic Train Protection:

In the proposed system there are no wayside signals except at stations with cross over. The signal aspects are repeated in the cab through appropriate display system (cab signalling). The speed profile is generated based on line data and train data continuously along the track. A braking curve is generated with respect to a defined target point and is monitored continuously. The maximum permitted speed on the sections and speed restrictions in force are also monitored and enforced if required. The ATP system maintains safety distance between trains. The system also monitors direction of travel and roll back. It enables releasing of doors on the correct side of the platform when train comes to a stop.

The train borne ATP sub-system ensures train locations based on odometer and track side beacons. It also exercises emergency braking control. It receives information from any station ATP sub-system about section ahead. It will authorize door opening authorization.

6.1.6 Automatic Train Operation:

Trains are normally driven automatically, but with Train Operator (TO) present in the front cab. The TO decides when the doors are closed and when it is safe for the train to depart a platform. The ATO function then takes over driving functions upto and including opening of the train doors on the correct side at next station. The ATO function is independent of ATP function and does not interfere with it. The ATO will also help optimization of energy consumption which is a very important factor. It also improves the ride quality and adheres to train scheduling better than when it is TO driven.

6.1.7 Automatic Train supervision:

It is a vital part of CATC and this system is responsible for the supervision, control and monitoring of train movements of the Railway in order to maintain intended traffic pattern and minimize the effects of train delay on the operating schedule. Its main functions cover traffic control, time table operation, service recovery after traffic disruption, maximization of system capacity, optimized energy economy, passenger information, traffic performance data, maintenance data logging and automatic dispatching of trains.

6.1.8 ATP, ATO and ATS are enabled by the following subsystems :

- Operation Control Centre (OCC) where trains are centrally controlled and monitored.
- Track to train communication system
- Electronic Interlocking.
- Communication channels from OCC to way station ATP sub-system

6.1.9 Operations Control Centre (OCC)

The rail system operations status will be continuously displayed on a mimic panel or other devices and work stations in the OCC. Route setting, track occupancy, point position and signal aspect will be mimicked and displayed in real time. The train identification will be by unique number and step in correspondence with the train movement. Supervision of train operations from OCC is envisaged automatically by ATS or by manual operation by the train controller. Normal working will be automatic route setting in accordance with the time table resident in ATS computer. The ATS system can generate new time tables for modifying train service operation by the CATC.

6.1.10 Track to train communication:

The track to train communication is essential for CATC system. This can be achieved through either AFTC which is used to detect presence of trains or through radio communication. The communication system transmits message to give advance information about status of track, points, route signals, block section, headway regulation, platform side etc.,

6.1.11 Electronic Interlocking :

a) **Station signalling**:

All stations where points are provided will be equipped with signalling to protect movement of trains and computer based interlocking (Electronic Interlocking) is proposed for stations for safe movement of trains. Station interlocking will adhere to CENELEC SIL-4 standard.

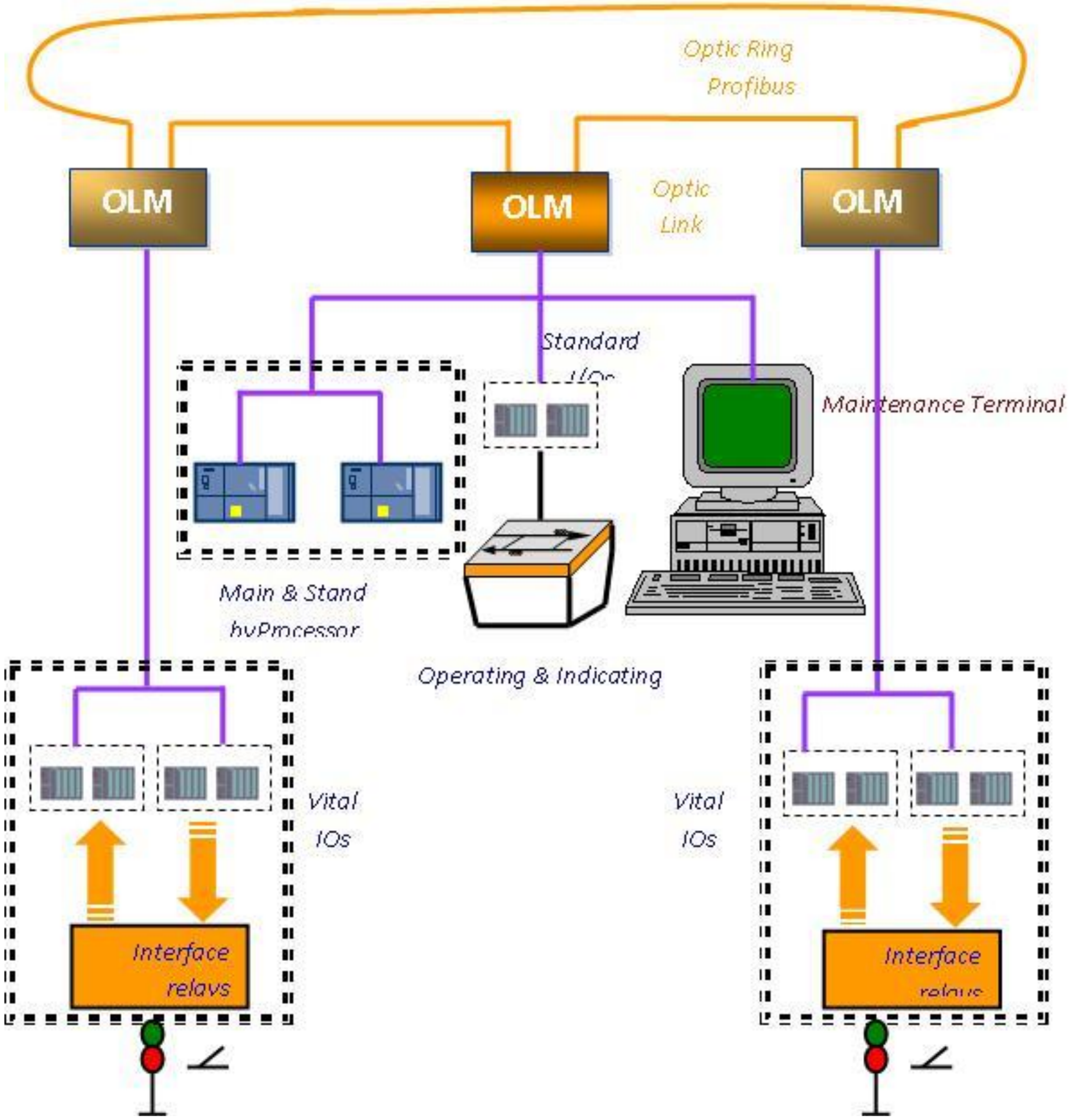


Figure 6-1: Station Inter locking System

b) **Depot signalling**:

Depot signalling controls movement of trains within in depot area. As a minimum, a vital two aspect line side signals is suggested to provide route setting and holding with indication of train locations displayed on a mimic panel and controlled from depot control centre. Signalled routes are interlocked against conflicting train movements without compromising operational flexibility. Trains will have to be transferred from depot lines to main service lines in safe and efficient manner. Interlocking will adhere to CENELEC SIL-4 standard.

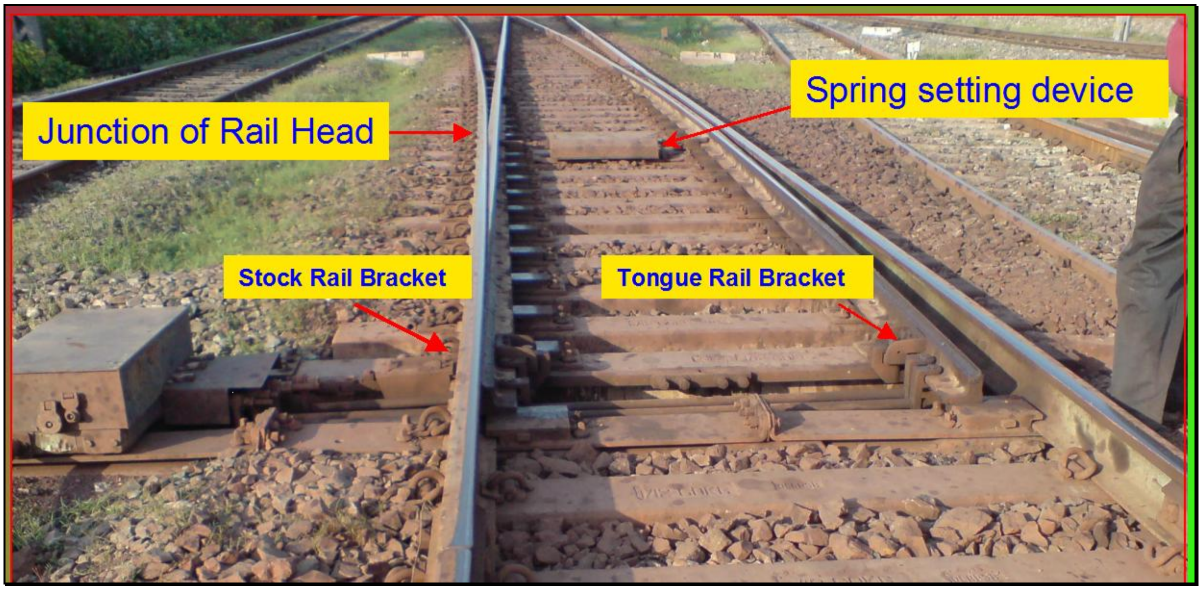


Figure 6-2: Illustrative Picture for Interlocking systems

6.1.12 Technology options and choice:

Many technology options are examined which can fulfil the requirements, brought out in previous paragraphs.

Though Automatic Train Protection, Automatic Train Operation and Automatic Train Supervision are discussed, the role of driver is not dispensed with. These are methods which can assist the driver and management and provide safe and efficient operation. With reference to the role of the driver and automation, there are four grades of automation which are defined as industry standard. These are shown in table 6-1 below:

Table 6-1: Grades of Automation

S.No.	Grade of Automation (GOA)	Type of train operation	Setting train in motion	Stopping train	Door closure	Operation in event of disruption
1.	GOA1	ATP with driver	Driver	Driver	Driver	Driver
2.	GOA2	ATP & ATO with driver	Automatic	Automatic	Driver	Driver
3.	GOA3	Driver less but attended train operation	Automatic	Automatic	Train attendant	Train attendant
4.	GOA4	Unattended Train Operation (UTO)	Automatic	Automatic	Automatic	automatic

While most metros operate on GOA2, some of older / low capacity ones operate as GOA1. For the proposed RRTS, GOA2 level is recommended taking into account the ATO benefits. After choosing the requirements of CATC and the level of automation the various technology options are examined with their salient features and tabulated in Table 6-2 below:

Table 6-2: Technology Comparison

S. No.	Technology	Head way	Use in	ATP	ATO	ATS	Reliability	Spectrum requirement	Standards	Cab signal
1.	Absolute Block	20 - 30 min	Conventional line	No	No	No	Limited by signal & block failures	No	No	No
2.	Automatic Block	5-6 min	Conventional line	No	No	No	Limited by track circuit & signal failure	No	No	No
3.	Automatic block +TPWS	5-6 min	Conventional line	Yes (limited way)	No	No	Limited by track circuit & signal failure	No	Partial for TPWS	No
4.	ERTMS-L1	> 3 Min	Conventional & High speed line	Yes	No	No	Limited by track circuit & signal failure	No	Yes	No
5.	ERTMS-L2	3 min	Conventional & High speed line	Yes	Yes	Yes	Limited by track circuit	Yes	Yes	Yes
6.	ERTMS-L3	<3 min	Conventional & High speed line	Yes	Yes	Yes	Not yet proven	Yes	Yes	Yes
7.	Train control 1G with trip stop	5-6 min	Metro	Yes limited	No	No	Limited by track circuit and signals	No	Yes	No
8.	Train control 2G-speed code signal	2-3 trains	Metro	Yes	Yes	Yes	Limited by track circuit	No	Yes	Yes
9.	Train control 3GDistance to Go system	2-3 min	Metro	Yes	Yes	Yes	Limited by track circuit	No	Yes	Yes
10.	Train control 4G-CBTC	90 sec	Metro	Yes	Yes	Yes	Limited by Radio (where redundancy can be provided)	No	Yes	yes

The three technology candidates which fulfil the level of automation and requirement of CATC are ERTMS level 2 and train control 3 G system (distance to GO signalling) and train control 4G CBTC (Communication based train control). These are discussed briefly.

6.1.13 ERTMS level – 2:

Even though it is emerging as world's leading signalling system for Railways, it is best known for its application in High Speed Lines (HSL) and conventional line. ERTMS level - 2 due to its capabilities in increase in capacity, is now becoming the system of choice for suburban lines around the world. However, it needs GSM – R radio, the spectrum for which will be a constraint in India. All the spectrum has been allotted to Indian Railways and RRTS may not get spectrum. Hence this option is ruled out.

6.1.14 Train Control 3rd Generation System:

This is also called the distance to go signalling system. It is fixed block system. If fulfils all the requirements. However, it needs AFTC for train detection and track to train communication. The reliability of the system will depend on reliability of AFTC. Hence proper attention is to be paid to installation methods, maintenance and opting for a proven reliable system. To ensure reliable performance of AFTC the track masts should not be connected to return rail and separate earth wire should be used connecting all masts to ground. This system is recommended for the RRTS. Most metros all over the world use this system.

6.1.15 Train control 4th Generation system:

It is also called the moving block. It does not warrant track circuits for train detection and data transmission. Hence, track circuit reliability is not a critical factor. However, it may need lesser number of track circuits / axle counter as a means and train detection, for operation during CBTC failure mode. Data transmission is through radio which operates in unlicensed spectrum and hence spectrum availability is not an issue. Reliability of subsystem used in lieu of track circuits for train detection and establishing train integrity is to be proven in Indian conditions. It is also costly, hence not recommended.

6.1.16 Signalling and Train Control Summary:

Considering the requirements of RRTS , 3rd Generation CATC System with Distance to Go signalling ; AFTC for Train detection ; Track to Train Data transmission ; Cab Signalling along with ATP, ATO, ATS is recommended .

6.2. Telecommunication

6.2.1 Introduction

The main purpose of the telecom system is to provide voice and data transmission capabilities throughout the rail transit system to enable efficient operation and management of the rail system. Instant communications independent from other means of communication is essential. The telecom requirement, structure, dimension and sophistication mainly depend on the structure of the rail transit network, train density and the working methods.

6.2.2 Train operation in RRTS:

Train operation in RRTS is characterized by the factors listed in the paragraph 6.1.2

6.2.3 Requirement of Telecom System:

(a) The communication system shall support and facilitate the functioning of the RRTS.

(b) The communication system shall be modern. The hardware and software offered shall be reliable in RRTS environment.

(c) The system shall provide safe, efficient and reliable operation.

(d) The system shall cater to communication needs of:

   i) Train traffic control

   ii) Features to supplement the signalling system

   iii) Maintenance and emergency communication

   iv) Passenger Information System (PIS)

   v) Exchange managerial information

vi) Clock system

vii) Station management system

viii) Train borne communication system.

ix) Data communication for signalling, SCADA, AFC etc.

(e) Operationally critical and safe working areas of the RRTS require backup with alternative communication system being provided.

(f) Be electromagnetically compatible with rolling stock, traction power, signalling systems.

(g) Permit easy expansion of all component systems by the addition of equipment and extension of networks with minimal effect on the operating systems.

(h) The network shall be designed in such a way that it is protected against:

i) Node failure

ii) Fibre failure (in case of OFC)

iii) Cable failure (in case of OFC)

6.2.4 The operation Telecom requirements:

These are summarized in a Matrix form shown in table 6-3 below:

Table 6-3: Telecom Requirements

S.No.	Information source	Information sink	Proposed communication arrangement	
			Normal	Emergency
1	OCC	Train Operator (TO)	Radio	Radio
2	TO	OCC	Radio	Radio
3	OCC	Passenger (in train)	Nil	Radio
4	Passenger in train	OCC	Nil	Nil
5	OCC	Passenger in station	OFC	OFC
6	Passenger in station	OCC	Nil	OFC
7	Station Master	Train	Radio	Radio
8	Train	Station Master	Radio	Radio
9	SM	OCC	OFC	OFC
10	OCC	SM	OFC	OFC
11	OCC	Maintenance Gang	Radio	Radio

S.No.	Information source	Information sink	Proposed communication arrangement	
			Normal	Emergency
12	Maintenance Gang	OCC	Radio	Radio
13	Maintenance Gang	SM	Radio	Radio
14	SM	Maintenance Gang	Radio	Radio
15	OCC	PA@Stn	OFC	OFC
16	OCC	PIS@Stn	OFC	OFC
17	OCC	Clock@Stn	OFC	OFC
18	OCC	Train PA	-	Radio
19	Station Video	OCC	OFC	OFC
20	OCC	Station Scada	OFC	OFC
21	Station	OCC (Scada)	OFC	OFC

In the above Matrix the various columns indicate the following:-

Information Source	=	Source where communication originates
Information Sink	=	Source where communication terminates
Proposed communication arrangement	=	Indicates the communication arrangement between source and sink in two scenarios: (a) Normal Case (b) During emergency / failure.

6.2.5 Description of operational telecom arrangements:

From the telecom matrix it emerges that there is need for the two types of communication arrangement:

(a) Back bone communication between fixed points along alignment. This can be through optical fibre

(b) Radio communication between fixed points and moving trains and mobile units

6.2.6 Back bone network:

Optical Fibre is the modern state of art cost effective telecom medium for back bone network. Hence the same is proposed for RRTS back bone communication all along the route. See table 6-4 for comparison of different media.

Table 6-4: Communication Medium Comparison

S. No.	Medium	Bandwidth	Repeaters	Theft proners	Distance limit	Maintenance cost	Spectrum required	Scalability	Electro Magnetic Interference
1.	Copper	Limited	more	Yes	Yes	Low	No	No	Yes
2.	OFC	Extremely high	Less	No	No	High	No	Yes	No
3.	Radio	Limited	More	No	No	Low	Yes	no	No

Further, the excess bandwidth of OFC can be leased to other users, thus earning money. To protect against fibre cut or node failure two optical fibre cables running on either side of tracks (path diversity) is proposed. The whole optical back bone network shall form a closed ring with the cables terminating at fiber patch panels at each station and OCC. Optical fibre cable (OFC) should be of steel armour protected type laid in troughs provided all along the elevated track side. Fiber optic cable shall be standard RDSO specification.

6.2.7 Data Transmission System (DTS)

DTS carries out the physical transfer of data or digital stream over a point to point or point to multipoint communication channel. Examples of such channels are copper wire, optical fibre, wireless communication channels. In the proposed back bone network the DTS transfer data over the optical fibre medium. The DTS can be either SDH or other applicable transmission networks system as per international standards such as ITU-T. (Example IP based data transmission network).

Since IP technology is fully matured it can be a viable option to SDH. Most of the devices (such as PA, clock, cameras) are also available with IP interface. IP based PABX are also matured in the market. The bandwidth provided by the DTS should match the loading required by the data speed of subsystem interfaces.

The DTS will cater to voice and data communication circuits or bandwidth for the following systems but not limited to:

(i) Public address system

(ii) Telephone system

(iii) Radio system

(iv) Closed circuit TV

(v) Passenger information display system (PIDS)

(vi) Clock system

(vii) SCADA system

(viii) AFC

(ix) Security and station management system

(x) Other data circuits or Ethernet ports as required.

The system connections to each of the above application need to be fire walled between each other to provide maximum security level.

It is also proposed to have at each station, sub-station, OCC and depot, local area network (LAN) to fast Ethernet standard for local data applications.

At OCC, a network management system (NMS) is envisaged to carry out the following:

(i) Real time monitoring and measurement need of telecom network status and performance

(ii) Prompt action to control the flow of traffic when necessary

(iii) Efficient and cost effective maintenance of the proposed communication network.

6.2.8 Public Address System (PAS)

PAS is proposed which will allow operators at stations, OCC to make announcements to the passengers / users while they are in station area. It is also proposed to broadcast announcement to the train through the radio system .The announcement to the PAS located at stations, terminals and depot can be made from OCC or station. To facilitate pre-recorded voice announcement a digital voice announcement system (DVAS) is proposed. Announcement from OCC can be to selected stations or all stations or to selected or all trains.

It is proposed to have stand alone or integrated system for the depot.

6.2.9 Telephone system

The staff working for the Rail system are provided with telephone services. The proposed staff telephone services can be divided into the two types:

(i) Private Automatic Branch Exchange (PABX) service for staff. This requires the staff to dial extension numbers. The PABX can be centralized or distributed along the system.

(ii) Direct to line telephone service for staff. This is mainly for controllers from OCC to call destination party using one touch button on the telephone sets for faster access.

A highly reliable digital main and satellite telephone exchange system is proposed for staff communication. Instead, one master telephone exchange can be installed at OCC with subscribers all over the system. They can be connected through OFC system. The telephone exchange / exchanges will cater to subscribers at OCC, stations, SP, SSP, depot and other important activity centres. In case of satellite exchanges, they will be connected to main exchange through OFC on DTS, either through EI or internet IP. Extension to Public Switched Telephone Network (PSTN) is also proposed. The exchange will also have interface to connect radio to handle radio call patching functions at OCC.

A digital Central Voice Recording system (CVR) is envisaged in OCC to record all telephone conversations of all controllers in OCC, depot, stations and other required locations. The telephone system will carry all modern features including voice mail.

The telephone system will have a battery backup for 2 hours.

The telephone exchanges are provided with terminals to industry standard.

6.2.10 Clock system:

The RRTS should have a clock system to display time at stations, OCC depots etc. It should provide synchronized time for the whole rail system. The time source can be derived from GPS. The synchronized time information shall be displayed on slave clock units through DTS. At each station a Station Master clock will receive the time information from DTS and convert it into synchronization pulses for the station slave clock units. The display clocks will be provided at all important locations as minimum requirement. Number of clocks, type of clock (digital or analog) and mounting methods can be detailed at DPR stage.

6.2.11 Passenger Information System (PIS)

The PIS enables the operators to send visual messages to the users while they are in the stations. These messages may be related to the following categories:

(i) Normal operating messages related to train arrival and departure or reminder messages to make users aware of proper and safe procedures.

(ii) Special operating messages such as informing users about train service delay

(iii) Emergency messages such as evacuation when there are hazardous conditions in the station.

Messages to PIS can be sent from:

(a) Station Master at stations

(b) Train Controller in OCC

(c) Chief Controller in OCC

(d) Depot Controller in OCC

(e) Commercial Controller in OCC

Suitable hardware can be provided at OCC and other message originating stations to input messages.

The messages from OCC can be sent to the stations via the DTS. Messages can also be sent to trains over the Radio system via suitable interfaces.

Display boards will be located in station public areas such as platforms, above ticket gates and at entrances.

Display hardware shall be of appropriate design for good viewing conditions. The hardware and software of display boards will support bilingual display (English & Hindi).

Train arrival information and pass through warning at stations should automatically be displayed on the corresponding platform display boards without operator intervention using inputs from signalling system.

6.2.12 Station Management System:

A Station Management System (SMS) is proposed at each station to control, status monitor and indicate failure alarm of station based electrical and mechanical facilities. This may be a computer based system. The SMS is proposed to be interfaced to DTS and connected to OCC from where monitoring can be done for normal and abnormal working. The functions of SMS envisaged are:

(i) Acquisition & processing of data from Remote Control Unit (RTU).

(ii) Alarm or enact handling and processing.

(iii) MMI for operator monitoring and control

(iv) Other technical features as required.

At each station the station master will have a work station to interact with SMS. A separate work station may be provided for the maintenance team. Similarly work stations at OCC will be provided for interaction with the SMS.

Some of the alarms proposed to be maintained at stations are, power supply, emergency power supply, AFC system, fire alarm panels, escalators, lighting, equipment room security system etc. The list is indicative and not exhaustive.

6.2.13 Closed Circuit Television (CCTV):

The CCTV system is proposed for video surveillance and recording functions for the operators to monitor each station and depot conditions. The following functionaries will have the CCTV monitoring facility.

(a) Station Master

(b) Station Security Incharge

(c) Platform Supervisor where available

(d) Operator at OCC

(e) Train driver when trains are stationary on platform. To enable this, monitor will be provided on platform in front at a suitable location.

(f) Depot Controller

(g) Any other functionary who will need CCTV facility.

Some of the cameras will have fixed location with fixed focus. Some cameras may have pan / tilt / zoom facility. The electrical signal output from cameras will be connected to DTS and to OFC at suitable interface (eg: Ethernet interface).

Cameras are envisaged in the areas where monitoring for security, safety and crowd control purpose is necessary, eg. Station platform area, ticket gate area, escalator landings, inside elevator, help point area, entrance & exit, evacuation routes and cash transfer routes, any other location that warrants video monitoring.

CCTV control panels will be provided for the staff monitoring at OCC, stations etc.

Digital video recorders can be provided at stations, OCC etc. to locally record selected camera pictures for historical replay.

6.2.14 Train borne communication system:

Train borne communication system is proposed to provide the following audio visual communication facilities on trains:

(i) One way announcement from Train Operator (TO) or driver to the users – using the train public address system.

(ii) Visual text message from TO to users – using the train borne passenger information system (PIS).

(iii) Two way conversation between TO and users – using passenger intercom unit.

(iv) Two way conversation between TO and traffic controller in OCC – using the train borne radio mobile unit.

(v) Two way conversation between TO and depot controller in depot – using the train borne radio mobile unit.

(vi) One way announcement from OCC to users – using train borne PA system and radio system.

(vii) Visual text messages from OCC to users – using train borne PIS together with OCC PIS system and Radio System.

(viii) Two way conversation between the front and rear cabs.

To enable the above a console panel will be integrated with the radio panel at each cab. The panels will have handset, speaker, selection key and other hardware required.

The display board for train borne PIS may be of LCD type or other alternatives which fulfils the viewing conditions and suitable to the environment in trains.

6.2.15 Radio system:

As can be seen from the communication matrix for information exchange with moving train and staff working along the track, radio medium is inescapable. The proposed radio system will provide wireless voice and data communications channels to support the operational and maintenance requirements of the rail system. Wireless voice communication channels are to be provided between the following parties:

(a) Traffic controller in OCC and Train operator for train regulation purpose.

(b) OCC and users on train (one way communication)

(c) Engineering Controller at OCC and O&M staff at track side

(d) Depot Controller and TO when trains are within depot area.

(e) Depot Controller and staff working in depot area

(f) Between O&M staff.

The Radio channels are also used to send out visual messages to the display boards on trains.

6.2.16 Choice of Technology:

The available Radio Technologies are:

(i) P25

(ii) DMR

(iii) TETRAPOL

(iv) TETRA

(vi) TETRA Release 2

(vi) GMS / GPRS / EDGE

(vii) CDMA

(viii) Wi Fi, WiMAX

(ix) UMTS (3G)

For the proposed RRTS environment, standard and security are of paramount importance. Without standards, it will be proprietary and life cycle cost will be high. The technologies which are available are compared on this basis and tabulated in table 6-5:

Table 6-5: Communication Technology Comparison

S.No.	Technology	Standard	Security	Spectrum use in India
1.	P25	Yes	Yes	No
2.	DMR	Yes	No	No
3.	TETRAPOL	No	Yes	No
4.	TETRA	Yes	Yes	Yes
5.	TETRA – Release 2	Yes	Yes	No
6.	GSM / GPRS/EDGE	Yes	No	Yes
7.	Wi MAX	Yes	No	Yes
8.	UMTS (3G)	Yes	No	Yes
9.	CDMA	Yes	No	Yes

Further, the radio system should meet the following challenges in RRTS:

(i) The radio system should work in limited frequency spectrum

(ii) Coverage should be good in urban canyons and tunnels

(iii) Since the RRTS is life line transport, the radio reliability should be excellent

(iv) The radio is used for train communication and safety is of paramount importance.

From the comparison table it can be seen that TETRA is best choice. Further TETRA has been accepted as de-facto technology for metro & subway and is a proven solution in metro rail all over the world.

TETRA base stations are built along the track to provide uninterrupted coverage all along the route. The optical fibre communication will provide the backbone connection from base station to OCC.

At OCC, a radio dispatcher work station is provided for the traffic controller to make radio communications with the TO on the trains. The controller will be able to call a particular train or a group of trains or all trains. The TO should also be able to initiate call to the controller at OCC. For better availability the dispatcher work stations should have back up arrangement

In the train, radio consoles and antenna will be provided at either end of trains.

The O&M staff will be provided with portable radio sets and will be able to talk among themselves or with Engineering Controller or depot controller. Group call facility will be provided in the TETRA system.

The radio coverage along the track shall be as per established standards.

6.2.17 Telecommunication in Tunnel :

The proposed RRTS has 39 km of Tunnel. For communication amongst fixed locations (stations etc), OFC can be extended. For extending Radio communication to the train and O& M staff, Leaky Coaxial cable with Bidirectional Repeaters is proposed. The Leaky Coaxial cable will be laid along the tunnel.

6.3. Ticketing and Access Control

a) Ticketing: Regional Rapid Transit Systems handle large number of passengers. Ticket issue and fare collection play a vital role in the efficient and proper operation of the system .To achieve this objective, ticketing system shall be simple, easy to use/operate and maintain, easy on accounting facilities, capable of issuing single/multiple journey tickets, amenable for quick fare changes and require overall lesser manpower. In view of above, computer based Automatic Fare Collection (AFC)system is proposed.

The proposed ticketing system shall be of Contactless Smart Token / Card type.

Figure 6-3: Smart Card and Smart Card Reader

The equipments for the same 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. Equipment and installation cost of Contactless Smart Card/Token based AFC system is similar to magnetic ticket based AFC system, but Contactless system proves cheaper due to reduced maintenance, less wear and tear and less prone to dusty environment.

Space for provision of Passenger Operated Machines (Automatic Ticket Dispensing Machines) for future, shall be provided at stations.

Automatic Fare Collection System proposed is similar to that installed in Delhi Metro Rail Corporation network.

Common Smart Card based ticketing for both RRTS and Bus systems is not proposed at this stage as this will require installation of AFC system at all RRTS stations and in buses also . A Clearing House system will also be required for separation of revenue among various operators. However, the proposed system shall have multi-operator capability and in future it will be possible to integrate various transport providers and other agencies by setting up a Clearing House and facilities at locations of other operators.

b) Access control: The access controlled areas at the stations have to be fenced and entry to them is to be restricted only to those having tickets / authorization to enter. For this purpose this area will be accessed only through gates either for entering or leaving this area. The use of tripod or turnstile type gates is not acceptable . The gate shall be capable of operating either in normally open or normally closed mode. Where required, barriers shall be provided to separate paid and unpaid areas of the concourse.

The barriers shall meet local public safety requirements and be aesthetically merged with station engineering.

Retractable flap type Control Gates are proposed which offer high throughput, require less maintenance and are latest in modern metro cities internationally.

Figure 6-4: Delhi Metro Smart Card

Tripod/turnstile type or flap type gates offer lesser throughput and require more maintenance.

The standards proposed for the Gates are as under:

Table 6-6: Gate Standards

S. No.	Standards	Description
I	Gates	Computer controlled retractable flap type automatic gates shall be at Entry and Exit .There will be following types of gates : a)**Entry** b)**Exit** c) **Reversible – can be set to Entry or Exit** d) **Wide reversible** gate for disabled people

6.4. Automatic Fare Collection System :

6.4.1 Automatic Fare Collection system proves to be cheaper than semi-automatic (manual system) in the long run due to reduced manpower cost for ticketing staff, reduced maintenance in comparison to paper ticket machines , overall less cost of recyclable tickets (Smart Card /Token) in comparison to paper tickets and prevention of leakage of revenue.

Relative advantages of Automatic Fare Collection system over manual system are as follows:

(a) Manual Fare Collection systems have the following inherent disadvantages:

i) Large number of staff is required for issue and checking of tickets.

ii) Change of fare structure is time consuming as has to be done at each station.

iii) Manipulation possible by jamming of mechanical parts.

iv) Staff and passenger interaction leading to more chances of confrontation.

v) 100% ticket checking at entry / exit impossible.

B) Automatic fare collection systems have the following advantages:

i) Less number of staff required.

ii) Less possibility of leakage of revenue due to 100%ticket check by control gates.

iii) Recycling of ticket fraudulently by staff avoided.

iv) Efficient and easy to operate, faster evacuation both in normal and emergency.

v) System is amenable for quick fare changes.

vi) Management information reports generation easy.

vii) System has multi-operator capabilities. Same Smart card can be used for other applications also.

viii) AFC systems are worldwide accepted systems for Metro cities environment.

6.4.2 Standards :

The standards proposed for AFC systems are as shown in table 6-7**:**

Table 6-7: AFC System Specifications

S. No	Standards	Description
i	Fare media	**Contactless Smart Token – For Single journey** : They shall have stored value amount for a particular journey .. Tokens are captured at the exit gate . **Contactless Smart Card** –For multiple Journeys :
ii	Station Computer, Central Computer and AFC Network	All the fare collection equipments shall be connected in a Local Area Network with a Station Server controlling the activities of all the machines .These Station Servers will be linked to the Central Computer situated in the Operation Control Center(OCC) through the Optic Fiber communication channels . The centralized control of the system shall provide real time data of earnings, passenger flow analysis , blacklisting of specified cards etc
iii	Ticket Office Machine (TOM/EFO)	Manned Ticket Office Machine shall be installed in the stations for selling cards/tokens to the passengers
iv	Ticket reader and portable ticket decoder	Ticket reader shall be installed near EFO for passengers to check information stored in the token/cards
v	UPS (Uninterrupted power at stations as well as for OCC)	Common UPS of S&T system will be utilized
vi	Maintenance philosophy	Being fully Contactless systems, manpower requirement for maintenance is much less compared to system with magnetic tickets. However, adequate facilities to be provided similar to that of S&T systems

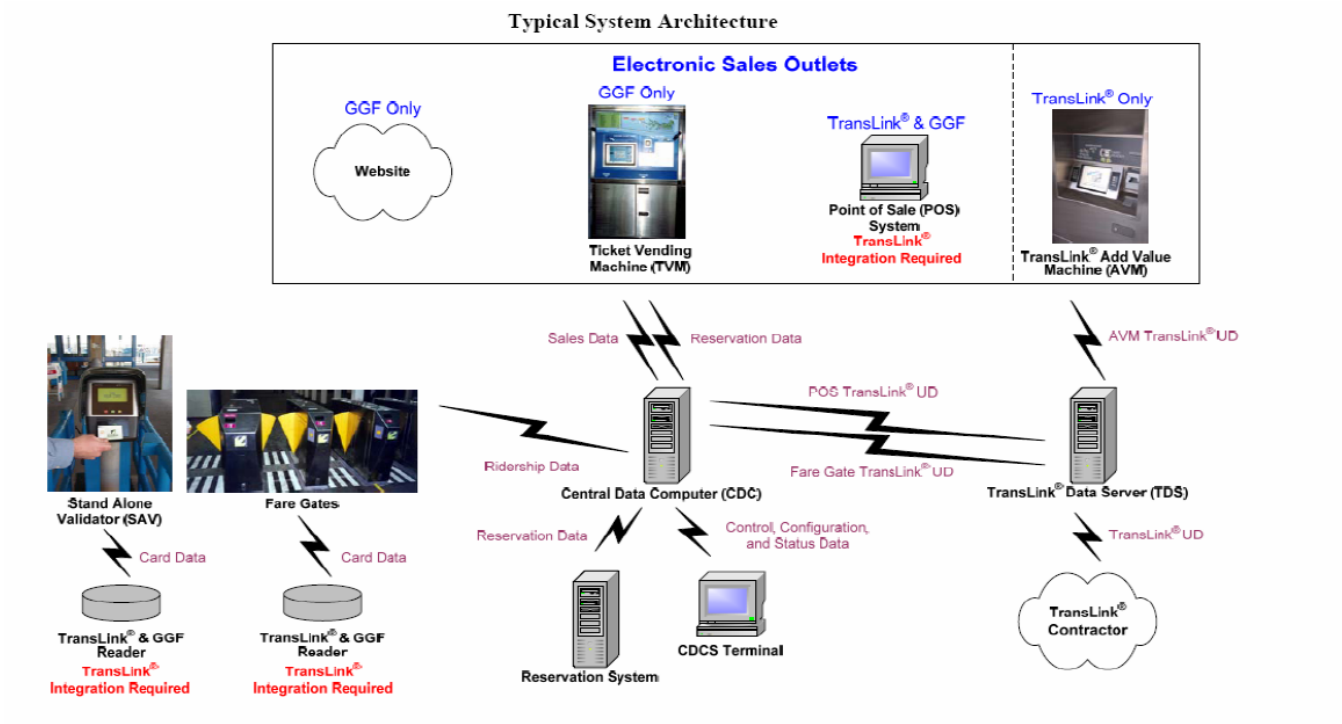


Figure 6-5: ITS Architecture for Fare Collection

6.4.3 Signalling, Train Control and Telecom Maintenance Philosophy and Requirements

Advanced Technologies as proposed for RRTS signal, train control and telecommunications have facilities which carryout supervision almost automatically. The staff necessary to operate and maintain these systems, however, must be skilled and well qualified.

Maintenance:

The objective of any maintenance procedure is to establish an acceptable service to the users by ensuring that the signalling and telecom equipment operate properly.

There are various management techniques that can be used to provide effective maintenance, such as fix-on-fail (reactive maintenance), scheduled preventive maintenance, periodic maintenance (inspection), reliability centered maintenance, conditions monitoring, redundancy, upgrade etc. They can be used singularly or more effectively in a combination of several types. Techniques such as fault trend analysis, Pareto analysis, six sigma, root cause analysis, bench marking and failure and effect analysis are all used today in maintenance management.

Maintenance methods:

(i) Corrective maintenance

Corrective maintenance is a maintenance activity which is required to correct a failure that has occurred or is in the process of occurring. This activity may consist of repair, restoration or replacement of components. The number of maintainers needed for maintaining a system and fault clearing measures depends on the average number of failures per equipment unit.

(ii) Preventive maintenance:

It is an equipment maintenance strategy based on replacing or overhauling an item at a fixed interval, regardless of its condition at the time. Scheduled restoration tasks and scheduled discard tasks are examples of preventative maintenance. Preventive maintenance becomes less important with modern electronics and telecom systems with large scale integrated components. Instead corrective maintenance is resorted to.

(iii) Qualitative maintenance:

Qualitative maintenance is a combination of preventive and corrective maintenance procedures. As full preventive maintenance is quite costly, preventive maintenance activities are concentrated exclusively on equipment where the effect of failures would spread widely.

The majority of equipment remain subject to corrective maintenance. The number of maintainers required is intermediate between the staff required for corrective maintenance and that for preventive maintenance procedures.

Choice of maintenance method:

Advanced digital systems usually apply qualitative maintenance. In this method, failure detection is performed regularly and printed out by automatic devices without the aid of maintainers. Fault clearing itself is quite often reduced to changing printed circuit cards. Qualitative maintenance assures a good average between corrective and preventive maintenance.

Grade of service:

An optimum O&M method has technical and organizational aspects. The quality demand leads to certain preventive procedures such as:

-Tele control

-Periodical measurements

-Equipment replacement

-Special maintenance systems

The equipment and system availability A is defined as

$$A = \frac{MTBF}{MTBF + MDT} \times 100\%$$

MTBF = Meantime between failures

MDT = mean down time

The availability is normally for a calculation period e.g. 3 months or one year.

For higher availability of the system the down time should be small which means that the repair time should be minimum. The repair time depends on skill of staff, storage place of spares and access time of staff to the site of failure. Hence, efficient transportation and strategic location of spares and maintenance personnel are important

Maintenance management strategy:

A central Network Monitoring and Control (NMC) facility is proposed to monitor signal and telecom equipment. The NMC may be separate for telecom (optical fibres, tetra base station, PA system etc. at different stations) and signal. Signal equipment such as AFTC, power supply etc., are amenable to remote monitoring. The essential functions of NMC are:

- Real time response to unexpected conditions
- Pre-planned actions to deal with recurring and predictable situations
- To effect speedy restoration of services in case of failures
- Timely measures to avoid / reduce future system problems
- Alternate routing of telecom traffic in case of fibre / equipment problems

The telecom and signalling sites are proposed to be unattended and will be monitored and controlled remotely. The state of art remote control systems are microprocessor controlled systems and the status of devices, subsystems and equipment are displayed on appropriate display diagrams.

There are two possible designs for monitoring configuration as follows:-

(i) One master station acting as a central unit for a number of other master stations with associated slave stations

(ii) Independent master stations for specific areas with associated slave stations

In view of the restricted geographic spread of the RRTS it is proposed to have one master station for the entire system at the OCC with slave stations spread along the route.

Maintenance staff will be grouped into two categories. First line maintenance staff for power plant, civil engineering and second line maintenance staff for optical fibre transmission equipment, DTS, base stations for TETRA, PAS etc. Similar arrangement is proposed for signalling and train control equipment.

First line maintenance staff will carryout routine power plant check and other alarm status of equipment. Second line maintenance staff will carry and detailed measurement, parameter check, system alignment etc., (predictive maintenance). In case of failure, first line maintenance staff will change the cards under the instruction and supervision and NMC or second line maintenance staff. The maintenance staff will be provided with transport and TETRA handset. The requirement of staff, spares and locations of staff and spares will depend on the MTBF of S&T equipment and can be worked out when these details are available. Maintenance should also be based as per recommendations of Original Equipment Manufacturers.

7. Rolling Stock

7.1. Introduction

The selection of Rolling Stock for the Delhi-Gurgaon-Rewari-Alwar RRTS has been done with the following objectives and requirements:

- The line is proposed to be Broad Gauge (1676 mm).
- Maximum operational speed 160 kmph.
- All trains operate at similar speed.
- 25 KV ac traction is proposed to be used
- The track is an elevated section for about 141km and underground section for remaining 39km.
- The stations are proposed at distance varying from 3.2 km to 7.5 km on underground section and 5.5 km to 29.5 km on elevated sections.
- Trains are controlled by Continuous Automatic Train Control (CATC) System.

7.2. Rationale for choice of important Rolling Stock parameters

7.2.1 Maximum Speed on Broad Gauge

Broad gauge is mainly prevalent on the Indian sub-continent comprising India, Pakistan and Bangladesh. On Indian Railways, the maximum permissible speed on most of the trunk routes is 110/120 kmph and on Tughlakabad – Jhansi and Ghaziabad – Kanpur sections is 130/140 kmph. However, several trials conducted on these two sections have established a safe maximum permissible speed of 160 kmph with LHB type coaches (German design) and 140 kmph with ICF type coaches. These speeds have not been implemented for want of certain other way-side and signalling requirements. However, the LHB coaches of similar design but on standard gauge on the European Railways are running at 250 kmph.

For DMRC Phase I on Broad Gauge, the coaches designed by ROTEM, Korea are designed for a maximum operating speed of 85 kmph. However, coaches with bogies of a similar design but on standard gauge are running on the Korean system at 200 kmph.

The only nearest comparison for commuter trains is with Bay Area Rapid TransIT (BART) in San Francisco, USA where broad gauge (1676 mm) coaches are operating with a maximum permissible speed of 130 kmph.

In view of the successful conversion of the original standard gauge coaches of LHB and ROTEM design for the broad gauge on Indian Railways, it is reasonable to assume that leading manufacturers will be able to offer a suitable coach design for broad gauge capable of running at a maximum operating speed of 160 kmph.

On underground sections, because of the higher train resistance, sharper curves and shorter inter-station distances, the advantage of setting a maximum operating speed exceeding 100 kmph is not much. For example, for a level section, the total journey time for the 34 km section with six stops comes to 1426 seconds with a maximum operating speed of 100 kmph. Increasing the speed to 120 kmph results in a saving of only 162 seconds. The gain will be even less for graded sections. Hence, the maximum operating speed in underground sections is proposed to be 100 kmph.

7.2.2 Coach Dimensions

On the BG sections of Indian Railways, conventional EMU coaches have a length of 20726 mm and width of 3658 mm. DMRC broad gauge coaches are 21640 mm long (DTC) and 3200 mm wide. BART (1676 mm gauge) coaches are 22860 mm long (with driving cab) and 3230 mm wide.

Generally, if the objective is to increase the passenger carrying capacity of a coach, increasing the length gives a better result because a wider coach is subjected to higher rolling, swaying, wheel-offloading and wind resistance at higher speeds. Of course, a longer coach also requires more liberal turn-outs; but, for a mainly elevated railway with large inter-station distances, as in the case of the proposed RRTS, this is not a significant issue.

Keeping the projected traffic and the coach dimensions being used elsewhere for similar systems in mind, a coach length of 22000 mm and width of 3200 mm was initially recommended. However, in view of the final decision conveyed by NCRPB vide letter no. K-14011/59/2009-NCRPB(Vol.X), dated 19.08.2011, 24 m long and 3.66 m wide coach dimension has been adopted for all calculations and analysis.

7.2.3 Wheel Diameter

UIC 510 allows a minimum wheel diameter of 680 mm for an axle load of 16 tonne. All Metro systems in India have adopted a new and worn wheel diameter of 860 and 780 mm respectively. With the proposed rail section of 60 kg (head hardened) 90 UTS for DGRA RRTS, it is reasonable to assume that the contact stresses will be within permissible limits for a 860 mm (new) and 780 mm (worn) wheel diameter.

7.2.4 Axle Load

On Indian Railways (IR) the existing axle load of passenger coaches is 13 tonne for non-AC and 16.25 tonne for AC coaches. The axle load of existing non AC EMU coaches on IR, having maximum speed of 100 kmph, is 20.32 tonnes.

On standard gauge high speed routes in Europe, an axle load of 18.35 tonnes (180 kN) is permitted up to 250 kmph speed (EUR-Lex Commission TSI Guidelines 2001).

After several rounds of discussions by the Consultancy Review Committee and a review by the Task Force, it has been decided that coach of 24 m length and 3.66 m width with transverse seating arrangement of 2 + 3 seats per row and having an axle load of 20 tonnes will be adopted for all the RRTS lines.

7.2.5 Maximum acceleration

Maintaining a constant acceleration requires a power output increasing in proportion to the square of speed. The train resistance also increases as a function of speed. Together, they cause the train to reach a point where the power output from the traction motors reaches its maximum value, after which the acceleration starts coming down, eventually reaching a value of zero. The speed at this point is called the balancing speed. A higher starting acceleration allows the maximum permissible or the balancing speed (whichever is achieved first) to be reached faster. However, for a given power output, the difference in terms of time or distance to reach this state is small in comparison to the total distance travelled between two successive stops. For Metro systems with typical inter-station distances of the order of 1 km, the starting acceleration and its sustainability are of importance; but, for systems with larger inter-station distances this does not make much difference to the total travel time between two stops for any value of starting acceleration between 0.9 m/s^2 and 1.3 m/s^2.

On the other hand, a higher acceleration calls for major issues to be addressed in the design of traction motors, propulsion system, gear couplings, bogie traction links and draft gear of the coaches.

On Metro systems, the starting acceleration is generally kept between the values of 0.9 m/s^2 and 1.0 m/s^2, sustainable up to speeds of between 30 to 35 kmph. On the EMU services of Indian Railways, the maximum acceleration is 0.35 m/s^2.

With the proposed tractive power of 4400 kW (comprising 16 traction motors of 275 kW each in a train set of six coaches), a starting acceleration of 1 m/s^2 will be sustained up to a speed of 34.7 kmph over a distance of 46.56 meters in 9.7 seconds on the on a straight level elevated section with full passenger load. Hence, a limiting starting acceleration of 1 m/s^2 is considered adequate for the proposed system.

7.2.6 Tractive Power requirement

A commuter train service with a high passenger occupancy (300+ persons per coach) makes it imperative that all or most of the power, propulsion, brake, control and HVAC equipment is housed either below the under frame or at the roof level, leaving most of the floor area for passenger occupation. Currently, it is a norm to house the entire HVAC system in the form of a Roof Mounted Package Unit (RMPU).

The most critical factor in this area is that of traction motor design. Ideally, every axle of the train can be powered, leading to very high acceleration, speed, braking and comparatively small longitudinal train dynamics. On a dc traction system, this becomes easier because the train does not require to be provided with two major equipment - main transformer and dc convertor.

On Metro Railway (Kolkata) and BART trains (on 750 V and 1000V dc respectively), all axles are powered. On Indian Railways EMU trains, only one out of every three coaches are powered with 4 X 167 kW motors for a maximum operating speed of 90 kmph. On DMRC, both for standard gauge and broad gauge systems, one out of every two coaches are powered with 4 X 220 kW motors. For the Delhi Airport Metro Express trains, every two out of three coaches are powered with 4 X 220 kW motors for a operating speed of 120 kmph. For the proposed Bangalore Airport Metro Link Express, the DPR envisages two out of every three coaches to be powered with 4 X 240 kW motors for a operating speed of 145 kmph.

A higher rating for the traction motor also means a bigger motor and, hence, a bigger bogie to accommodate it. The bogie wheel base is constrained by the considerations of curving and higher flange forces on curves and turn-outs. Traction motor size is also constrained by considerations of mechanical clearance from the rail level. Higher tractive power also means matching transformers, convertors and invertors for the propulsion system all of which not only need to be housed below the floor level but also increase the axle load.

Our calculations for the originally recommended coach size of 22 m X 3.2 m with an axle load of 16 tonnes showed that for a six-coach train formation with four motor coaches with 16 X 250 kW traction motors can achieve the maximum operating speed of 160 kmph on a straight level section in 137 seconds over a distance of 4187 meters and 131 kmph balancing speed on a continuous up gradient of 1 in 50 on elevated track. The total theoretical journey time for the entire 180 km route with 16 stops can be covered within one hour forty five minutes (without dwell time) even with the most unfavourable gradient (1 in 50 continuous) conditions. Hence, a total tractive power of 4000 kW for a six-coach train set with 250 kW traction motors on two out of every three coaches was recommended to achieve the objective of restricting the total journey time within two hours.

However, with a coach size of 24 m X 3.66 m with an axle load of 20 tonnes, the traction power requirement has increased to 4400 kW comprising 16 traction motors of 275 kW each, on 4 motor coaches of a 6 coach train. With this augmentation, the total journey time over the entire 180 km route will increase marginally (by 26 seconds considering an entirely level section and 3 mins 10 seconds for 1 in 50 up gradient). Hence, we recommend 275 kW traction motors.

7.2.7 Auxiliary Power requirement

The most significant requirement among all auxiliary requirements is that of HVAC system. It is the general norm for Railway rolling stock to design the system for maintaining a temperature of between 23^0 C to 27^0 C corresponding to a relative humidity of 65 %. On the mainline AC coaches of Indian Railways, the AC equipment has a total power rating of 45 to 50 kW comprising two roof mounted packaged units to take care of the passenger load. On DMRC coaches both for standard and broad gauge, there are two roof mounted units of 54 kW each with a separate 9 kW unit for each driving cab. DMRC's experience shows that this is adequate to take care of a passenger load per coach. Therefore, it is proposed to keep the HVAC power rating for RRTS as 2 X54 kW units.

The other auxiliary power requirements are for lighting, headlights and taillights, public address system, passenger information display, door operation, main and auxiliary compressors, various pumps and blowers for the power equipment and control circuits. The total auxiliary power requirement for a train set of six coaches is estimated as 1000 kW.

7.2.8 Total Train Power Requirement

The total train power output requirement comprises traction and auxiliary requirements. Taking an overall system efficiency of 85% for traction and 90% for auxiliary loads, the input power requirement for a 6 coach train will be about 6300 kW.

7.2.9 Car body Design

While for the major load-bearing structural parts of the underframe, the common practice is to use hot-rolled corrosion resistant steel, for the car body shell either austenitic stainless steel or medium strength aluminium alloys are used. The aluminum-bodied coaches are costlier than stainless steel ones but reduce the coach weight by about 1.5 to 2 tonnes. The exiting and upcoming Metro systems in India have largely gone for stainless steel. The Indian manufacturers of Metro and EMU coaches have also shown a preference for stainless steel. The stainless steel manufacturers have also built up capabilities to make sheets and rolled sections of various types required for coach-building. Aluminum alloy technology and manufacturing capabilities have not developed to a similar extent.

In keeping with the overall trend in India, it is proposed to adopt stainless steel bodied coaches for the proposed system.

7.2.10 Passenger Loading Density and Seating Arrangement

Norms for passenger loading density varies from country to country depending on economic conditions, capacity or willingness to pay and the overall transportation objectives of the operator. It also depends on overall journey time and profile of the travelling public. Generally, metro or suburban systems go for a minimal seating arrangement with most of the floor space kept free for standing passengers. Dedicated services for airport links, on the other hand, cater for a largely sitting accommodation.

Following the Transit Co-operative Research Programme (TCRP) guidelines, the total capacity for a 24m X 3.66m coach has been worked out to 100 seating and 126 standing (normal density) and 328 standees (dense crush@8 persons/sqm standee area) giving a total capacity of 226 (normal) and 428 (dense crush) respectively.

The driving cab is to be designed ergonomically with multiple interactive LCD monitors for the driver to set train operational parameters, public announcements, performance monitoring and trouble-shooting along with interaction with ATP, OCC and Train radio.

These will be of modular sub-assemblies for each function for easy maintenance and replacement. While the equipment will be fitted by the suppliers of the ATP/ATC/Train radio, the car manufacturer will provide cubicles, racks and shelves for the equipment along with the necessary power cables and protective devices.

7.2.11 Propulsion System

In keeping with the present state of the art, the propulsion system will be ac-dc-ac type with three-phase squirrel cage type traction motors, PWM based variable voltage variable frequency (VVVF) propulsion control and IGBT based convertors and invertors.

7.2.12 Major Rolling Stock Specifications

Table 7-1: Rolling Stock Specification

Item	Specification
Rail gauge	1676 mm
Supply Voltage System	25kV AC single phase 50Hz
Current Collection	Through Pantograph
Type of Car	
DMC	Driving Motor Car
MC	Motor Car
TC	Trailer Car
Train Composition	
6-Cars	DMC-TC-MC-MC-TC-DMC
9-Cars	DMC-TC-MC-MC-TC-MC-MC-TC-DMC
Car Tare Weight (Max)	
DMC	50 tonne
MC	49 tonne
TC	48 tonne
Maximum Number of passengers	428 (seating – 100, standing – 328)
Axle Load	20 tonnes
Wheel Diameter	860 mm (New)
	780 mm (Fully worn)
Speed Control System	Control of acceleration and deceleration by Variable Voltage, Variable Frequency (VVVF) Inverter blended with regenerative braking
Brake System	Regenerative braking blended with electro-pneumatic braking by electrical command and pneumatic back-up brake
Train Performance	
Maximum design Speed	180 kmph
Maximum Operational Speed	160 kmph (with inflated secondary suspension)
	130 kmph (with deflated secondary suspension)
	100 kmph in tunnel section

Item	Specification
Service braking rate from 160 kmph to standstill for fully loaded train on level track	1.0 m/s^2 ±5%
Emergency braking rate from 160 kmph for fully loaded train on level tangent track	1.3 m/s^2 ±5%
Jerk rate	0.7 m/s^3 at 160 kmph
Bogie Type	Bolster less with two stage suspension
Suspension Type	
Primary	Conical bonded rubber spring
Secondary	Air spring
Automatic Train Control System	CATC with ATP, ATO & ATS
Train Monitoring System	Train Integrated Management System (TIMS)
Saloon Air Conditioning System	
Type Cooling Capacity Heating Capacity	Roof-mounted and Self-contained Type 54 kW per unit at design conditions 11 kW
Door System	
Passenger Saloon Door	Electrically driven, plug-swing, flush, synchronised, sliding bi-parting door 1400 mm (W) X 1900 mm (H)
Cab Side Door	Manually Operated Pocket Sliding Door
Saloon to Cab Door	Manually Operated hinged single leaf Door

7.2.13 Specification of Major Equipment

Table 7-2: Major Equipment Specification

ITEM	SPECIFICATION
Carbody	
Maximum Length over couplers	24000 mm
Maximum width of Body	3660 mm
Locked down pantograph height	4050 mm
Height of floor from Top of Rail (TOR)	1130 mm Maximum, 1100mm Minimum
Height of the coupler center from the top of rail	800 +10, -5 mm
Interior Panel	Semi-Nomax Honey Comb.
Window Glass	Double glazed, toughened, laminated glass separated by an air gap.
Bogie & Driving Gear Unit	
Bogie type	Bolsterless type bogie with air spring

ITEM	SPECIFICATION
Friction braking system	
Motor car bogie	Wheel disc with double shoe
Trailer car bogie	Wheel disc with double shoe
Driving gear unit	One-Stage helical gear with bipartite housing
Gear ratio	105/19 (5.526:1)
Traction Motor	
Type	Squirrel cage type 3 phase induction motor
Continuous rating	275kW
Gear Ratio	105/19
Design Max. revolution	6000 rpm
Cooling method	Self-ventilated type
Converter / Inverter	
Control method	Voltage source PWM inverter
Control capacity	550 kW × 2 per motor coach
Main Transformer	
Catenary Voltage and frequency	25kV, 50Hz ±3%
Rating	3600 kVA X 1 per trailer coach
Auxiliary Power Supply Unit (SIV)	
Main Circuit	IGBT Converter + IGBT inverter
Output rated voltage	AC 3-phase 415V 350 kVA AC 230V 1 phase 2 wired, 20 kVA 110VDC +5%, -5%, 25 kW
Coupler	
At free ends of DMC Between two 3-coach units Between coaches of same unit	Automatic type w/o electrical coupler Automatic coupler with electrical head Semi-permanent muff couplers
Compressive strength	1250 kN(Yield strength)
Tensile strength	850 kN(Yield strength)
Shock absorption capacity	approx. 900 kN ± 10%(on buff), 100 kJ
Impact load absorption capacity	approx. 1200 kN ± 10% (4x300 kN), 24 kJ

8. Power Supply and Traction

8.1. General

8.1.1 Description of the Corridor

The Delhi-Gurgaon-Rewari-Alwar Rail-based Regional Rapid Transit System (RRTS) is approximately 180 km long. Out of the total length of 180 km, approximately 39 km is Underground, from ISBT (KG) to IFFCO Chowk including, and the remaining 141 km is proposed to be elevated.

Stations are proposed at distances varying from 3.2 km to 7.5 km in the Underground Section and from 3.8 km to 29.5 km in the elevated section. There are in all 19 Stations, out of which, 08 are Underground and 11 are Elevated.

8.1.2 Other Features of the Line

Trains would be controlled by Automatic Train Control System. Trains are proposed to be run at an operating speed of 160 kmph on Electric Traction, with Electric Multiple Units (EMU). The EMU's are with closed-door operation and are air-conditioned.

8.1.3 Electric Power Requirement

The requirement of Electric Power for Train Operation will depend upon the loading of trains, including the number of cars per train and the headway. For purposes of estimating the electric power requirement, the following train operation plans are considered for various horizon years.

Table 8-1: Coach Requirement per Rack

Year	Train Composition	Headway (in Minute)
2016	6 Cars	6
2021	6 Cars	5
2031	9 Cars	6
2041	9 Cars	5

6-Car trains will be composed of DMC+TC+MC+MC+TC+DMC and 9-Car trains of DMC+TC+MC+MC+TC+MC+MC+TC+DMC.

The maximum traction and auxiliary power demand of a 6-Car train and 9-Car train are given in Table 8-2.

Table 8-2: Power Requirement for Train

Item	Train Composition	
	6-Car train	9-Car train
Traction Power	4 x 4 x 275 kW = 4400 kW	6 x 4 x 275 kW = 6600 kW
Auxiliary Power	6 x 125 kW = 750 kW	9 x 125 kW = 1125 kW
Total	**5150 kW**	**7725 kW**

In addition, electric power will be required at the Stations and along the Alignment, to meet the following requirements

- Station auxiliary services (eg lighting, escalators, elevators, pumps, air conditioning of various functional rooms etc)
- Tunnel ventilation (in Underground Stations and Tunnels)
- Signalling and Telecommunication
- Maintenance Depots and other Maintenance infrastructure within the premises of the Metro System
- Property Development (like food-courts, Traveller's Requirement Shops, ATM's etc.)

A preliminary estimate of the electric power requirement for traction and auxiliary purposes, is included in this Report. In addition, the Report also describes

- The System for distribution of Traction Power (choice of traction system) and Auxiliary Power, along the Alignment
- Tentative locations where from Electric Power can be purchased, namely the various Grid Substations (GSS) of the State Electricity Authorities

- Tentative locations of Receiving Substations (RSS) along the Alignment, where from power will be fed to the RRTS.

8.2. Choice of Electric Traction System

8.2.1 General

There are several systems of Electric Traction, including

DC Systems

- 750V / 1500V Third Rail System
- 1500V / 3000V Overhead System

AC Systems

- 16 2/3 Hz AC System
- 50 Hz, 25 kV, Single Phase AC System
- 50 Hz, 2x25 kV, Single Phase, Auto-transformer AC System

The DC System has generally the following disadvantages over the AC System

- Due to comparatively lower voltages, the feedings Substations have to be located very close to each other, to avoid heavy voltage drops
- For the same power, the currents to be handled are very high in the DC System and handling of heavy currents may lead to over-heating at joints and increase the risk of fire.
- Due to heavy currents to be handled, the conductor sizes also become high
- On account of requirement of more feeding Substations and comparatively higher conductor sizes, the cost of system also increases substantially.

As compared to the DC System, 25 kV AC System will be cheaper, but will require larger clearances. Hence, in environments where adequate electrical clearances can be ensured, as in the RRTS Corridor, the choice will fall upon 25 kV AC System. The choice between 1x25 kV AC System and 2x25 kV AC System, is discussed in the following paragraphs.

8.2.2 Comparison between 1x25 kV AC and 2x25 kV AC Systems

1x25 kV AC System can be with or without Booster Transformers (Booster Transformers are required to be provided in the 1x25 kV AC System, only when the Alignment is very close to important telecom lines or telecom exchanges, which should be protected from the electromagnetic induction effects of the 1x25 kV AC Traction System). The 2x25 kV AC System will not require any Booster Transformers but should be provided with Auto-transformers and hence is generally referred to as 2x25 kV AC AT System. (The functions of Autotransformers and Booster Transformers are explained in the Sketches below). Basically, in 1x25 kV AC System, the Traction Power distribution is at 25 kV, with the Traction Overhead Equipment (OHE) at +25 kV and the Rail at nearly zero potential. In 2x25 kV AC System, the Traction Power distribution is at 50 kV, with the Traction Overhead Equipment (OHE) at +25 kV, the return feeder (negative feeder) at (-)25 kV and the rail at nearly zero potential. This gives the 2x25kV System an advantage that the Feeding Substations can be comparatively spaced further apart. The main features of the 2 Systems are compared below.

8.2.3 Spacing of Substations

The spacing between Substations depends, to a large extent, on the train headway. It the train headway is short, the spacing also has to be closer. If the train headway is large, the spacing can be longer. As a general indication, the max possible spacing between 2 consecutive substations is shown in Table 8-4.

Table 8-3: Substation spacing

Power Supply System	Max Possible Spacing (km)	
	Short Headway (≤10 min)	Long Headway (>10 min)
1 x 25 kV AC	45	65
2 x 25 kV AC	75	100

8.2.4 Voltage Regulation

Feeding Circuit Impedance for 2 x 25 kV AC System is less than that for 1 x 25 kV AC System. As a general indication, for a feeding distance of, say 30 km, the feeding Circuit Impedance for 1 x 25 kV AC will be approximately 2.5 times that of 2 x 25 kV AC.

It is this difference in Impedance, which makes it possible to space the Substations farther apart in the case of 2 x 25 kV AC System, as compared to 1 x 25 kV AC System.

8.2.5 Auto Transformers

Auto transformers (AT) will be required to be installed at regular intervals in the case of 2 x 25 kV AC System.

At spacing will depend upon the following

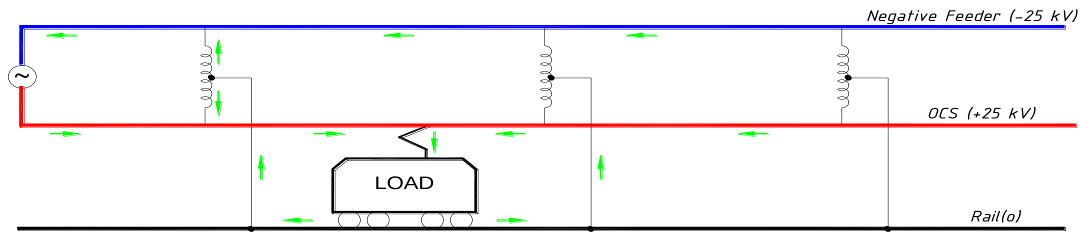
- Where there are vital telecommunication lines in close vicinity, shorter AT spacing will be required, to reduce electromagnetic interference.
- For better voltage regulation, shorter AT spacing will be required
- To limit the Rail potential to within permissible values, shorter AT spacing will be required

A spacing of 12-15 km between AT's will generally, be required.

(In Bina-Katni-Annupur Section of Indian Railways, the approximate average spacing between AT's is about 15 km).

The function of AT's vis-a-vis BT's is explained in the following sketches.

SKETCH-1



SKETCH-2

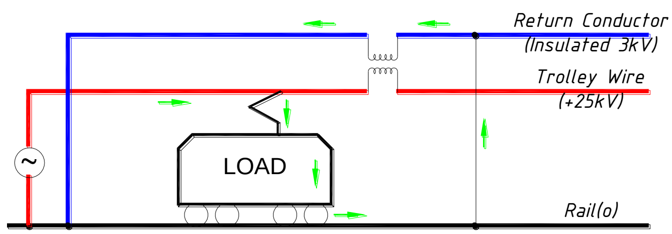


Figure 8-1: 1X25 KV AC with Booster Transformers

Negative Feeder

A Negative Feeder insulated for 25 kV will be required (See Sketch 1 above) throughout the Section if 2 x 25 kV is used.

If 1 x 25 kV AC is used a Return Conductor, insulated for 3 kV will be required (see sketch 2 above) in specific portions of the Section.

Sensitivity to Reduced levels of Operation

2 x 25 kV AC System will generally be justified only when high-tonnage freight trains or high speed (more than 250 kmph) passenger trains at close headway, are envisaged. When the project is designed and constructed with 2 x 25 kV AC Power Supply System, and when it takes time to reach the projected level of traffic, the assets will remain under-utilised during the intervening period thereby leading to higher costs of overall performance. On the contrary, it is possible to design and construct the project for a level of traffic projected for the near future with 1 x 25 kV AC and it can, thereafter, be augmented/upgraded when the traffic reaches higher levels if required.

8.2.6 Technology Level

With more than 30000 km of track electrified on 1x25 kV AC System in Indian Railways, there is adequate technical know-how, manufacturing facilities and maintenance skill, available locally. However, the 2x25 kV AC System with its new components like Auto-transformers, Neutral Current Ratio Type locator devices, Capacitance-Resistance devices to suppress harmonic oscillations, Fault locators etc, will require a Maintenance organization which will need to upgrade its technical and technological level. Indian Railways had electrified approximately 400 km of line on 2 x 25 kV AC System, during 1995-96 and there had been no additions on 2 x 25 kV AC thereafter, during the last 15 years.

Substantial inputs in the form of training facilities, training courses, Specialist trainers etc will be required to ensure satisfactory design, construction, operation and maintenance of 2 x 25 kV AC System.

8.3. Comparative Costs

8.3.1 Capital costs

For purposes of comparing the capital costs of the two systems, the Benchmark costs under the following major heads are taken into account.

a) Power Supply
b) Traction Overhead Equipment
c) Auxiliary Power Distribution System
d) Supervisory Control And Data Acquisition (SCADA) System
e) Cost of obtaining HV Power Supply from State Power Supply Authorities

Table 8-4: Comparative Cost Estimates

Sr. No.	Item	Approx. Estimated Costs (Rs Lakhs)					
		1 x 25 kV AC			2 x 25 kV AC		
		Qty.	Unit Cost	Total Cost	Qty.	Unit Cost	Total Cost
A - Power Supply							
1	Traction Substations (Nos.)	4	2940	11760	3	3550	10650
2	Feeding Posts (Nos.)	4	385	1540	3	655	1965
3	Sectioning Posts (Nos.)	3	60	180	2	330	660
4	Subsectioning Posts (Nos.)	9	45	405	5	312	1560
5	AT Stations (Nos.)	NIL	NIL	NIL	5	270	1350
6	BT Stations (Nos.)	28	55	1540	NIL	NIL	NIL
	Sub Total			**15425**			**16185**
B – Traction Overhead Equipment							
7 a)	Flexible OHE on Elevated Section (Track km)	315	75	23625	315	75	23625
7 b)	Rigid OCS in Underground Tunnels (Track km)	81	110	8910	81	133	10773
	Sub Total			**32535**			**38178**
C – Auxiliary Power Distribution System							
8 a)	33 kV Cabling in Elevated Sections (Network km)	303	25	7575	303	23	6969
8 b)	33 kV Cabling in Underground Sections (Network km)	78	68	5304	78	68	5364
9 a)	33 kV / 415 kV Auxiliary Transformers at 11 Elevated Stations (2 Transformers each of 630 kVA, per station)	22	22	484	22	22	484
9 b)	33 kV/415 kV Auxiliary Transformers at 8 Underground Stations (3 Transformers each of 2500 kVA, per station)	24	49	1176	24	49	1176
10	33 kV Switchgear for 19 Stations	126	12	1512	126	12	1512
11	Control Equipments at 19 Stations (11 x 1 +8 x 2)	27	13	350	27	13	350

Sr. No.	Item	Approx. Estimated Costs (Rs Lakhs)					
		1 x 25 kV AC			2 x 25 kV AC		
		Qty.	Unit Cost	Total Cost	Qty.	Unit Cost	Total Cost
12	Power Supply arrangement along the Alignment – Power Sockets (Nos.)	6000	0.25	1500	6000	0.25	1500
	Sub Total			**17901**			**17901**
D – Supervisory Control And Data Acquisition System (SCADA)							
13	SCADA System Equipments at Operation Control Centre (LS)	1	2200	2200	1	2200	2200
14	Substation Control Equipments (Sets)	4	40	160	3	48	144
15	Control Equipment at Switching Stations	16	16	256	10	22	220
16	Control Equipments at AT Stations	NIL	NIL	NIL	6	12	72
	Sub Total			**2616**			**2636**
E – Cost of Obtaining 132 kV Power Supply							
17	HV Bays Equipments at Power Supply Authority Substation (Nos.)	4	470	1880	3	470	1410
18	132 kV Double Circuit Transmission Line (Circuit Km)	80	60	4800	60	60	3600
	Sub Total			**6680**			**5010**

All figures in lakhs.

Table 8-5: Total Estimate Cost

Item	Total Estimated Cost (Rs Lakhs)	
	1 x 25 kV AC	2 x 25 kV AC
Power Supply	15425	16185
Traction Overhead Equipment	32535	38178
Auxiliary Power Supply	17901	17901
SCADA	2616	2636
132 kV Power Supply	6680	5010

Item	Total Estimated Cost (Rs Lakhs)	
	1 x 25 kV AC	2 x 25 kV AC
Miscellaneous	9395	9988
General Charges @ 6%	5073	5394
Contingencies @ 3%	2689	2859
Total	**92314**	**98151**

Figures in Lakhs.

Thus the Capital Cost of 2x25 kV AC system for the corridor is estimated to be 6.5% higher than 1x25 kV AC system

8.3.2 Operation & Maintenance Costs

General

A comparison between the Operation & Maintenance Costs for the 2 Systems, viz 1x25 kV AC and the 2x25 kV AC System, has been made under the following heads.

- Operation cost, including Energy
- Maintenance of electrical equipment
  - Periodical Maintenance
  - Replacement cost of asset

Operation Cost, including Energy

Operation Cost

The cost of operation of the Power Supply System, including Remote Control from the Operations Control Centre (OCC) does not materially differ for the 2 Systems viz 1x25 kV or 2x25 kV.

Energy Cost

In the 2x25 kV System, the power is being fed from the Substations at 2x25 =50 kV. This makes it necessary to provide Autotransformers at periodic intervals where one end of the Auto-transformer winding is connected to the OHE (+25 kV), the other end to the Negative feeder (-25 kV) and the mid-point to the Rail (0 kV). These Auto-transformers are constantly in circuit and are a source of energy loss, in addition to the losses occurring in the Substation Transformers.

The Japanese Consultants, who were engaged by the IR, in 1986, for making a detailed techno-economic evaluation of the 2x25 kV AT System, prior to its introduction in the Annupur-Bina Section, had studied the subject of 'Energy losses' in the 3 possible alternative systems for electrification viz (i) 25 kV Simple feeding system (without BT), (ii) 25 kV BT System and (iii) 2x25 kV AT System. Their Study had revealed that "AT feeding system has the largest loss in feeding circuit, followed by BT System and the Simple Feeding System".

- The Auto-transformers (about 2500 kW capacity) installed every 12-15 km along the feeding circuit, contribute substantially to energy losses.
- In the BT System, the Booster Transformers which have generally a capacity of 100 kVA – 150 kVA, have lesser losses, while in 'Simple Feeding System' where there are no BT's at all, there are no losses in this account.

An approximate estimation is made of the Energy losses in the Booster Transformers (for 1x25 kV BT System) and in the Auto-transformers (for 2x25 kV system)

(a) Estimated energy losses in Booster Transformers (1x25 kV BT)

(i)	Length of elevated line	=	141 km (approx)
(ii)	Approx Section length where BT's would be required to be provided (say 50%)	=	70.5 km
(iii)	No. of BT Stations @ 1 BT Station every 2.66 km	=	26.5 (say 28)
(iv)	No. of BT's, each of capacity 150 kVA	=	2 x 28 = 56
(v)	Approx. loss	=	56 x 150 x 0.8 x 1% = **67 kW**

(b)Estimated energy losses in AT (2x25 kV)

AT's will be required both in elevated and Underground Section

(i)	Length of Line	=	180 km (approx)
(ii)	No. of AT Stations @ 1 AT Station every 12-15 km	=	15 (Auto-transformers are provided at Substations, Sectioning Posts, SSP's and Auto-transformer Posts)
(iii)	No. of AT's, each of capacity say 2000 kw	=	30
(iv)	Approx. loss	=	30 x 2500 x 1.15% = 863 **kW**

From the above it could be observed that the 2 x 25 kV AT System results in an extra energy loss of approximately (863-67) = 796 kW. This is equivalent to approximately 6.97 Million Units (kWh) of electrical energy per annum.

At an estimated energy cost of Rs 4.50 per kWh, the additional expenses on energy, on this account, will work out to Rs 31 Million (Rs. 3.1 crores) per annum.

8.3.3 Maintenance of Electrical Equipment

Periodical Maintenance

The Maintenance cost depends generally on the population of Electrical equipment and also on the complexity of the equipment. In the case of 1 x 25 kV AC System as well as the 2 x 25 kV AC System, the electrical equipments used, such as Circuit Breakers, Isolators, Lightning Arresters etc are more or less similar, except that some of them are bi-polar in 2 x 25 kV AC System. However, there are certain additional items like Negative feeders, Auto-transformers, fault locator using AT Neutral Current ratio etc, used in the 2 x 25 kV System, which will result in more maintenance requirements. A very rough list of additional items/elements required to be maintained in the 2 x 25 kV AC System, is as follows

- Auto-transformers
- Negative feeder wire itself

- Negative feeder supporting devices
- 25 kV support insulators for feeder
- Motorised Switches
- Lightning Arresters

At the same time Booster Transformers and Return Conductors are not existing in the 2 x 25 kV AC System, and since the number of Neutral Sections are less, the maintenance requirement against Neutral Section will also reduce. The net total impact on the cost of preventive maintenance can be approximately estimated as follows.

(Note : Please note that these are not the absolute values of annual O&M costs. Items which are common for both systems are not considered for comparison, since they do not have any impact on the comparative costs.)

Table 8-6: Operating Cost Comparison

Item	Description	Cost in (Rs Lakhs)	
		1 x 25 kV AC	2 x 25 kV AC
1	Capital cost of electrical systems		
a)	Power Supply	15425	16185
b)	OHE	32535	38178
c)	Total	47960	54363
2	Annual preventive Maintenance Cost (@1% of Capital Cost for 1x25 kV AC System and 1.15% of Capital Cost for 2x25 kV AC System)	479.60	625.17

From the above, it may be seen that the 2x25 kV AC System will require additionally approximately Rs 1.46 crores per annum over the 1 x 25 kV AC System, towards periodical maintenance.

8.3.4 Replacement Cost of Asset

Considering a span of 30 years, some of the electrical equipments, such as motorised isolators, synthetic insulators and some connecting cables may require replacement. Since their population is more in the 2 x 25 kV AC System, the cost of replacement also will be higher. The life span of various electrical equipments varies from equipment to equipment. While items like contact wire, synthetic insulators, batteries etc may have a life span less than 30 years, some other items like HV Switchgear, Power Transmission lines etc may have life span more than 30 years. For assessing the replacement cost, a generalised life span of 35 years is assumed. Based on this, the replacement cost of assets in the case of 2x25 kV AC System will be more than that for 1x25 kV AC System, by approximately Rs (54363- 47960) x (1/35) lakhs = 182.94 lakhs (Rs 1.83 crores) per annum.

8.3.5 Comparative Cost of O&M

From the above, it could be seen that the comparative figures of Operation Maintenance cost for 2 x 25 kV System and 1 x 25 kV AC System will be as follows.

Table 8-7: Maintenance Cost Comparison

Sr. No.	Item	Comparative Figures	
		1 x 25 kV AC	2 x 25 kV AC
1	Operation Cost	No difference	
2	Energy losses	-	More losses costing approx Rs. 3.10 crores/year
3	Periodical Maintenance	-	More by approx Rs 1.46 crores/year
4	Replacement cost of asset	-	More by approx Rs 1.83 crores/year

Thus, on a general assessment, it is seen that the Operation & Maintenance Costs of the traction system in the corridor with the 2 x 25 kV AC System may be more than that in the 1 x 25 kV AC System by approx Rs 6.4 crores / year.

8.3.6 Recommendation

The comparison of the above parameters reveals that for the Project under consideration, the advantages of adopting 1x25 kV AC System for Traction Power Supply outweigh the disadvantages. In view of the above, it is recommended to adopt the 1x25 kV AC System (with Booster Transformers and Return conductors wherever required) for the RRTS Corridor Delhi- Gurgaon- Rewari- Alwar. This matter has also been discussed in the CRC and a final decision has beeen taken to adopt 1X25kV AC traction system for RRTS.

8.4. POWER SUPPLY

8.4.1 Power Requirements

General

Electric Power is required for

- Running of electric trains (traction power)
- Station auxiliary services (eg lighting, escalators, elevators, pumps, air-conditioning of various functional rooms etc)
- Tunnel Ventilation.
- Signalling and Telecommunication
- Maintenance Depots and other Maintenance Infrastructure within the premises of the Metro System
- Property development (like food-marts, Travellers Requirement Shops, ATM’s etc)

A Preliminary estimate of the Power Requirement is made in the succeeding paragraphs.

8.4.2 Power for Traction

The Traction Power requirement is estimated based on the peak-hour demand of the trains, taking the following factors into consideration.

(i) Specific Energy consumption : 75 kWh/1000 GTkm

(ii) Power factor of Traction load : 0.95

(iii) Energy Losses : 5%

(iv) Regeneration : 15% (However, the Regeneration factor is not taken into account, while estimating power requirement, transformer capacity etc).

The Traction Power requirement will obviously depend upon the headway of train operation, total train weight etc. For purposes of calculating the approximate traction power requirement, the following values of the above parameters are taken into account, for various horizon years.

Table 8-8: Train Headways

Horizon Year	2016	2021	2031	2041
No. of cars per train	6	6	9	9
Headway	6 mins	5 mins	6 mins	5 mins

The following calculations show the approximate traction power requirement for various horizon years.

Table 8-9: Traction Power Requirement

Description	Unit	Year			
		2016	2021	2031	2041
No. of Cars	Nos.	6	6	9	9
No. of DMC	Nos.	2	2	2	2
No. of MC	Nos.	2	2	4	4
No. of TC	Nos.	2	2	3	3
Tare Weight DMC	Tonne	50	50	50	50

Description	Unit	Year			
		2016	2021	2031	2041
Tare Weight MC	Tonne	49	49	49	49
Tare Weight TC	Tonne	48	48	48	48
Total Train Tare Weight	Tonne	294	294	440	440
No. of Passengers DMC	Nos.	400	400	400	400
No. of Passengers MC	Nos.	428	428	428	428
No. of Passengers TC	Nos.	428	428	428	428
Total Passengers in Train	Nos.	2512	2512	3796	3796
Total Passenger Weight (@ 70kgs per passenger)	Tonne	175.8	175.8	265.7	265.7
Total Train Weight	Tonne	469.8	469.8	705.7	705.7
Length of Line	**km**	**180**	**180**	**180**	**180**
Headway	Mins.	6	5	6	5
No. of Trains per hour, in both directions	Nos.	20	24	20	24
Total GTKm	'000	1691	2030	2541	3049
Specific Energy Consumption	kWh/1000 GTKm	75	75	75	75
Peak Traction Power requirement	MW	127	152	191	229
Regenration	%	NIL	NIL	NIL	NIL
Max Power Demand with energy loss of 5% and pf of 0.95	MVA	141	169	211	253
Depot Traction Power requirement @ 1 MVA / 1.5 MVA per Depot (3 Depots)	MVA	3	3	4.5	4.5
Total Traction Power requirement	**MVA**	**143.6**	**171.7**	**215.6**	**257.9**

From the above, it could be seen that during the initial year of operation (2016), the power requirement for traction will be about 143.6 MVA, increasing to a demand of 257.9 MVA in the year 2041.

8.4.3 Power for Auxiliary Services

The estimate of Power for Auxiliaire Services includes the Power requirement for Station Auxiliary Services, for Signalling and Télécommunication, for Maintenance Depots and for property development.

The Auxiliary Power requirement is based on the following

(i) Elevated Stations - In the initial years, ie upto 2021, the requirement is taken as 300 kVA per station, which will increase to 500 kVA in the subsequent years.

(ii) Underground Stations - The requirement in the initial years, ie upto 2021, including power required for tunnel-ventilation air-conditioning in essential locations in stations etc, is taken as 2000 kVA per station, which will increase to 2500 kVA in the subsequent years.

Based on the above, the Auxiliary Power requirement for various horizon years will be as follows.

Table 8-10: Auxiliary Power Requirement 2016/2021

Description	Unit	Auxiliary Power requirement (for Year 2016/2021)				
		Dhaula Kuan	Panchgaon	MBIR	Khairtal	Total
No. of Underground Stations	Nos.	8	0	0	0	8
No. of Elevated Stations	Nos.	0	4	4	3	11
Power required per U/G Station	kVA	2000	2000	2000	2000	2000
Power required per Elevated Station	kVA	300	300	500	500	300
Auxiliary Power requirement at Maintenance Depots (3 Depots)	kVA	2000	0	2000	2000	6000
Total Auxiliary Power requirement	MVA	18.0	1.2	3.2	2.9	25.3

Table 8-11: Auxiliary Power Requirement 2031/2041

Description	Unit	Auxiliary Power requirement (for Year 2016/2021)				
		Dhaula Kuan	Panchgaon	MBIR	Khairtal	Total
No. of Underground Stations	Nos.	8	0	0	0	8
No. of Elevated Stations	Nos.	0	4	4	3	11
Power required per U/G Station	kVA	2500	2500	2500	2500	2500
Power required per Elevated Station	kVA	500	500	500	500	500
Auxiliary Power requirement at Maintenance Depots (3 Depots)	kVA	3000	0	3000	3000	9000
Total Auxiliary Power requirement	MVA	23.0	2.0	5.02	4.5	34.5

From the above it could be seen that during the initial year of operation (2016), the power requirement for Auxiliary purposes will be about 25.3 MVA, which will increase to 34.5 MVA in the year 2041.

8.5. Total Projected Power Demand

The total approximate Projected Power demand for the various horizon years, is as follows.

Table 8-12: Project Power Demand

Description	Unit	Year			
		2016	2021	2031	2041
Traction Power requirement	MVA	144.0	172.0	215.5	257.5
Auxiliary Power requirement	MVA	25.3	25.3	34.5	34.5
Total Power Demand	MVA	169.3	197.3	250.0	292.0
Rounded off	MVA	170.0	200.0	250.0	300.0

8.6. Source of Power Supply

The DGRA RRTS Corridor passes through Delhi, Haryana and Rajasthan States. The electric Power required for train operation and auxiliary purposes is, therefore, required to be sourced from the Electric Power Supply Authorities of these States. With a view to obtain confirmations from the Power Supply Authorities, discussions were held with them and the following are the results of discussions.

8.6.1 Delhi Transco Limited (DTL)

During the discussion with the Executive Director DTL has advised that electric power would be made available, at 66 kV, from their Vasant Kunj Grid Substation, located approximately 6-7 km from the proposed RRTS RSS at Dhaula Kuan.

8.6.2 Haryana Vidyut.

HVPNL have confirmed that power supply for the RRTS would be made available at

- Panchgaon
- MBIR (HVPNL have also stated that they could provide HV power alternatively at Rewari, if required. However, from point of view of land availability etc. it is preferable to locate the RSS in MBIR, where the Car Depot is also proposed to be located.

8.6.3 Rajasthan Vidyut

RVNL have confirmed that HV power at 132Kv would be made available at Khairthal.

In view of the above, the following Sources are identified for Receiving Power for the **RRTS Corridor.**

Table 8-13: Sources of Power

Sr. No.	Name of RRTS Receiving Substation	Power Supply Authority
1	Dhaula Kuan	DTL
2	Panchgaon	HVPNL
3	MBIR	HVPNL
4	Khairthal	RVNL

8.6.4 Reliability of Power Supply

In order to ensure reliability of Power Supply, duplicate feeders (Underground cables or Overhead transmission lines) will be run between the Grid Substations and the Receiving Substations. In addition, the Power Supply Design will have the following built-in redundancies.

a) If one out of the 2 adjacent Substations, becomes totally out-of-service, it would be possible for the healthy Substation to meet the load requirements, by using extended feed condition. While doing detailed designing, it would require to be examined as to whether, for the train operation during the horizon year 2041, it would be necessary to regulate the services or not.

b) If one out of the 2 transformers installed at any Substations becomes totally out-of-service, the healthy transformer will be able to meet the entire load requirements (100% hot standby arrangement).

c) The Auxiliary Power to meet station auxiliary loads, tunnel ventilation etc, will be distributed from the RSS via duplicate 33 kV, 3 phase feeders (cables) along the viaduct and in the tunnel. This will ensure that even when one feeder circuit is faulty, the healthy feeder will be able to feed the power to all Auxiliary Substations (ASS).

d) In Underground Stations and in elevated stations, every ASS will be provided with 2 Auxiliary Transformers, each rated to meet the full load requirement, one acting as a 100% standby to the other. Hence, even if one transformer is totally out-of-service, the healthy transformer will be able to meet the full load requirement, normally catered for the ASS.

e) In addition, redundancy will be provided for strategically important Switchgear, so that the interruptions to traffic as a result of electrical equipment failures, are very minimal.

8.7. Traction Power Supply

8.7.1 Traction Substations

Considering the total Traction Power demand for the horizon year 2041, which is around 257.9 MVA, and with a view to keeping the voltage drop to within acceptable limits when 9-car trains will require to be run during 2041, the number and locations of Traction Substations will require to be decided now, considering the requirement of the horizon year 2041. The Transformer rating and the feeding system can be designed with reference to the requirements during the various intervening years.

Tentatively 04 Traction Substations are proposed to be located at

- Dhaula Kuan : Km 20.00
- Panchgaon : Km 64.00
- MBIR : Km 101.00
- Khairthal : Km 155.50

Based on the above proposed locations of Traction Substations and the proposed train operation plan for various years, the estimated peak hour max demand at various Traction Substations, is as shown in Tables 8-14 to 8-21.

Table 8-14: Dhaula Kuan TSS (Feeding towards New Delhi)

Description	Unit	Year			
		2016	2021	2031	2041
No. of Cars	Nos.	6	6	9	9
No. of DMC	Nos.	2	2	2	2
No. of MC	Nos.	2	2	4	4
No. of TC	Nos.	2	2	3	3
Tare Weight DMC	Tonne	50	50	50	50
Tare Weight MC	Tonne	49	49	49	49
Tare Weight TC	Tonne	48	48	48	48

Description	Unit	Year			
		2016	2021	2031	2041
Total Train Tare Weight	Tonne	294.0	294.0	440.0	440.0
No. of Passengers DMC	Nos.	400	400	400	400
No. of Passengers MC	Nos.	428	428	428	428
No. of Passengers TC	Nos.	428	428	428	428
Total Passengers in Train	Nos.	2512	2512	3796	3796
Total Passenger Weight (@ 70 KG per passenger)	Tonne	175.8	175.8	265.7	265.7
Total Train Weight	Tonne	469.8	469.8	705.7	705.7
Length of Line	**km**	**20.0**	**20.0**	**20.0**	**20.0**
Headway	Mins.	6	5	6	5
No. of Trains per hour, in both directions	Nos.	20	24	20	24
Total GTKm	'000	187.9	225.5	282.3	338.7
Specific Energy Consumption	kWh/1000 GTKm	75	75	75	75
Peak Traction Power requirement	MW	14.1	16.9	21.2	25.4
Regeneration	%	NIL	NIL	NIL	NIL
Max Power Demand with energy loss of 5% and pf of 0.95	MVA	15.6	18.7	23.5	28.2
Depot Traction Power requirement @ 1 MVA / 1.5 MVA	MVA	1	1	1.5	1.5
Total Traction Power requirement	**MVA**	**16.6**	**19.7**	**25.0**	**29.7**

Table 8-15: Dhaula Kuan TSS (Feeding towards Rajiv Chowk)

Description	Unit	Year			
		2016	2021	2031	2041
No. of Cars	Nos.	6	6	9	9
No. of DMC	Nos.	2	2	2	2
No. of MC	Nos.	2	2	4	4
No. of TC	Nos.	2	2	3	3
Tare Weight DMC	Tonne	50	50	50	50
Tare Weight MC	Tonne	49	49	49	49
Tare Weight TC	Tonne	48	48	48	48
Total Train Tare Weight	Tonne	294.0	294.0	440.0	440.0
No. of Passengers DMC	Nos.	400	400	400	400

Description	Unit	Year			
		2016	2021	2031	2041
No. of Passengers MC	Nos.	428	428	428	428
No. of Passengers TC	Nos.	428	428	428	428
Total Passengers in Train	Nos.	2512	2512	3796	3796
Total Passenger Weight (@ 70kgs per passenger)	Tonne	175.8	175.8	265.7	265.7
Total Train Weight	Tonne	469.8	469.8	705.7	705.7
Length of Line	**km**	**21.5**	**21.5**	**21.5**	**21.5**
Headway	Mins.	6	5	6	5
No. of Trains per hour, in both directions	Nos.	20	24	20	24
Total GTKm	'000	202.0	242.4	303.5	364.2
Specific Energy Consumption	kWh/1000 GTKm	75	75	75	75
Peak Traction Power requirement	MW	15.2	18.2	22.8	27.3
Regeneration	%	NIL	NIL	NIL	NIL
Max Power Demand with energy loss of 5% and pf of 0.95	MVA	16.8	20.1	25.2	30.3
Depot Traction Power requirement	MVA	0	0	0	0
Total Traction Power requirement	**MVA**	**16.8**	**20.1**	**25.2**	**30.3**

Table 8-16: Panchgaon TSS (Feeding towards Rajiv Chowk)

Description	Unit	Year			
		2016	2021	2031	2041
No. of Cars	Nos.	6	6	9	9
No. of DMC	Nos.	2	2	2	2
No. of MC	Nos.	2	2	4	4
No. of TC	Nos.	2	2	3	3
Tare Weight DMC	Tonne	50	50	50	50
Tare Weight MC	Tonne	49	49	49	49
Tare Weight TC	Tonne	48	48	48	48
Total Train Tare Weight	Tonne	294.0	294.0	440.0	440.0
No. of Passengers DMC	Nos.	400	400	400	400
No. of Passengers MC	Nos.	428	428	428	428
No. of Passengers TC	Nos.	428	428	428	428
Total Passengers in Train	Nos.	2512	2512	3796	3796
Total Passenger Weight (@ 70 Kg per passenger)	Tonne	175.8	175.8	265.7	265.7

Description	Unit	Year			
		2016	2021	2031	2041
Total Train Weight	Tonne	469.8	469.8	705.7	705.7
Length of Line	**km**	**22.5**	**22.5**	**22.5**	**22.5**
Headway	Mins.	6	5	6	5
No. of Trains per hour, in both directions	Nos.	20	24	20	24
Total GTKm	'000	211.4	253.7	317.6	381.1
Specific Energy Consumption	kWh/1000 GTKm	75	75	75	75
Peak Traction Power requirement	MW	15.9	19.0	23.8	28.6
Regeneration	%	NIL	NIL	NIL	NIL
Max Power Demand with energy loss of 5% and of of 0.95	MVA	17.6	21.1	26.4	31.7
Depot Traction Power requirement	MVA	0	0	0	0
Total Traction Power requirement	**MVA**	**17.6**	**21.1**	**26.4**	**31.7**

Table 8-17: Panchgaon TSS (Feeding towards BTK)

Description	Unit	Year			
		2016	2021	2031	2041
No. of Cars	Nos.	6	6	9	9
No. of DMC	Nos.	2	2	2	2
No. of MC	Nos.	2	2	4	4
No. of TC	Nos.	2	2	3	3
Tare Weight DMC	Tonne	50	50	50	50
Tare Weight MC	Tonne	49	49	49	49
Tare Weight TC	Tonne	48	48	48	48
Total Train Tare Weight	Tonne	294.0	294.0	440.0	440.0
No. of Passengers DMC	Nos.	400	400	400	400
No. of Passengers MC	Nos.	428	428	428	428
No. of Passengers TC	Nos.	428	428	428	428
Total Passengers in Train	Nos.	2512	2512	3796	3796
Total Passenger Weight (@ 70 Kg per passenger)	Tonne	175.8	175.8	265.7	265.7
Total Train Weight	Tonne	469.8	469.8	705.7	705.7
Length of Line	**km**	**22.0**	**22.0**	**22.0**	**22.0**
Headway	Mins.	6	5	6	5

Description	Unit	Year			
		2016	2021	2031	2041
No. of Trains per hour, in both directions	Nos.	20	24	20	24
Total GTKm	'000	206.7	248.1	310.5	372.6
Specific Energy Consumption	kWh/1000 GTKm	75	75	75	75
Peak Traction Power requirement	MW	15.5	18.6	23.3	27.9
Regeneration	%	NIL	NIL	NIL	NIL
Max Power Demand with energy loss of 5% and pf of 0.95	MVA	17.2	20.6	25.8	31.0
Depot Traction Power requirement	MVA	0	0	0	0
Total Traction Power requirement	**MVA**	**17.2**	**20.6**	**25.8**	**31.0**

Table 8-18: MBIR TSS (Feeding towards BTK)

Description	Unit	Year			
		2016	2021	2031	2041
No. of Cars	Nos.	6	6	9	9
No. of DMC	Nos.	2	2	2	2
No. of MC	Nos.	2	2	4	4
No. of TC	Nos.	2	2	3	3
Tare Weight DMC	Tonne	50	50	50	50
Tare Weight MC	Tonne	49	49	49	49
Tare Weight TC	Tonne	48	48	48	48
Total Train Tare Weight	Tonne	294.0	294.0	440.0	440.0
No. of Passengers DMC	Nos.	400	400	400	400
No. of Passengers MC	Nos.	428	428	428	428
No. of Passengers TC	Nos.	428	428	428	428
Total Passengers in Train	Nos.	2512	2512	3796	3796
Total Passenger Weight (@ 70 Kg per passenger)	Tonne	175.8	175.8	265.7	265.7
Total Train Weight	Tonne	469.8	469.8	705.7	705.7
Length of Line	**km**	**15.0**	**15.0**	**15.0**	**15.0**
Headway	Mins.	6	5	6	5
No. of Trains per hour, in both directions	Nos.	20	24	20	24
Total GTKm	'000	141	169	212	254
Specific Energy Consumption	kWh/1000 GTKm	75	75	75	75

Description	Unit	Year			
		2016	2021	2031	2041
Peak Traction Power requirement	MW	10.6	12.7	15.9	19.1
Regeneration	%	NIL	NIL	NIL	NIL
Max Power Demand with energy loss of 5% and pf of 0.95	MVA	11.7	14.1	17.6	21.1
Depot Traction Power requirement @ 1 MVA / 1.5 MVA	MVA	1	1	1.5	1.5
Total Traction Power requirement	**MVA**	**12.7**	**15.1**	**19.1**	**22.6**

Table 8-19: MBIR TSS (Feeding towards SNB)

Description	Unit	Year			
		2016	2021	2031	2041
No. of Cars	Nos.	6	6	9	9
No. of DMC	Nos.	2	2	2	2
No. of MC	Nos.	2	2	4	4
No. of TC	Nos.	2	2	3	3
Tare Weight DMC	Tonne	50	50	50	50
Tare Weight MC	Tonne	49	49	49	49
Tare Weight TC	Tonne	48	48	48	48
Total Train Tare Weight	Tonne	294.0	294.0	440.0	440.0
No. of Passengers DMC	Nos.	400	400	400	400
No. of Passengers MC	Nos.	428	428	428	428
No. of Passengers TC	Nos.	428	428	428	428
Total Passengers in Train	Nos.	2512	2512	3796	3796
Total Passenger Weight (@ 70 kg per passenger)	Tonne	175.8	175.8	265.7	265.7
Total Train Weight	Tonne	469.8	469.8	705.7	705.7
Length of Line	**km**	**25.0**	**25.0**	**25.0**	**25.0**
Headway	Mins.	6	5	6	5
No. of Trains per hour, in both directions	Nos.	20	24	20	24
Total GTKm	'000	234.9	281.9	352.9	423.4
Specific Energy Consumption	kWh/1000 GTKm	75	75	75	75
Peak Traction Power requirement	MW	17.6	21.1	26.5	31.8
Regeneration	%	NIL	NIL	NIL	NIL

Description	Unit	Year			
		2016	2021	2031	2041
Max Power Demand with energy loss of 5% and pf of 0.95	MVA	19.5	23.4	29.3	35.2
Depot Traction Power requirement	MVA	0	0	0	0
Total Traction Power requirement	**MVA**	**19.5**	**23.4**	**29.3**	**35.2**

Table 8-20: Khairthal TSS (Feeding towards SNB)

Description	Unit	Year			
		2016	2021	2031	2041
No. of Cars	Nos.	6	6	9	9
No. of DMC	Nos.	2	2	2	2
No. of MC	Nos.	2	2	4	4
No. of TC	Nos.	2	2	3	3
Tare Weight DMC	Tonne	50	50	50	50
Tare Weight MC	Tonne	49	49	49	49
Tare Weight TC	Tonne	48	48	48	48
Total Train Tare Weight	Tonne	294.0	294.0	440.0	440.0
No. of Passengers DMC	Nos.	400	400	400	400
No. of Passengers MC	Nos.	428	428	428	428
No. of Passengers TC	Nos.	428	428	428	428
Total Passengers in Train	Nos.	2512	2512	3796	3796
Total Passenger Weight (@ 70 Kg per passenger)	Tonne	175.8	175.8	265.7	265.7
Total Train Weight	Tonne	469.8	469.8	705.7	705.7
Length of Line	**km**	**29.5**	**29.5**	**29.5**	**29.5**
Headway	Mins.	6	5	6	5
No. of Trains per hour, in both directions	Nos.	20	24	20	24
Total GTKm	'000	277.2	332.6	416.4	499.6
Specific Energy Consumption	kWh/1000 GTKm	75	75	75	75
Peak Traction Power requirement	MW	20.8	24.9	31.2	37.5
Regeneration	%	NIL	NIL	NIL	NIL
Max Power Demand with energy loss of 5% and pf of 0.95	MVA	23.0	27.6	34.6	41.5
Depot Traction Power requirement	MVA	0	0	0	0
Total Traction Power requirement	**MVA**	**23.0**	**27.6**	**34.6**	**41.5**

Table 8-21: Khairthal TSS (Feeding towards Alwar)

Description	Unit	Year			
		2016	2021	2031	2041
No. of Cars	Nos.	6	6	9	9
No. of DMC	Nos.	2	2	2	2
No. of MC	Nos.	2	2	4	4
No. of TC	Nos.	2	2	3	3
Tare Weight DMC	Tonne	50	50	50	50
Tare Weight MC	Tonne	49	49	49	49
Tare Weight TC	Tonne	48	48	48	48
Total Train Tare Weight	Tonne	294.0	294.0	440.0	440.0
No. of Passengers DMC	Nos.	400	400	400	400
No. of Passengers MC	Nos.	428	428	428	428
No. of Passengers TC	Nos.	428	428	428	428
Total Passengers in Train	Nos.	2512	2512	3796	3796
Total Passenger Weight (@ 70 Kg per passenger)	Tonne	175.8	175.8	265.7	265.7
Total Train Weight	Tonne	469.8	469.8	705.7	705.7
Length of Line	**km**	**24.5**	**24.5**	**24.5**	**24.5**
Headway	Mins.	6	5	6	5
No. of Trains per hour, in both directions	Nos.	20	24	20	24
Total GTKm	'000	230.2	276.3	345.8	415.0
Specific Energy Consumption	kWh/1000 GTKm	75	75	75	75
Peak Traction Power requirement	MW	17.3	20.7	25.9	31.1
Regeneration	%	NIL	NIL	NIL	NIL
Max Power Demand with energy loss of 5% and pf of 0.95	MVA	19.1	23.0	28.7	34.5
Depot Traction Power requirement @ 1 MVA / 1.5 MVA	MVA	1	1	1.5	1.5
Total Traction Power requirement	**MVA**	**20.1**	**24.0**	**30.2**	**36.0**

Summarising, the power demands at various Traction Substations, are estimated as shown in table 8-22.

Table 8-22: Summary of Traction Substation Power Distribution

Sr. No.	Traction Substation	Traction Estimated Power Demand (MVA)	
		2016	2041
1	Dhaula Kuan	33.4	60.0
2	Panchgaon	34.8	62.7
3	MBIR	32.2	57.8
4	Khairthal	43.1	77.5

From the above, it could be seen that, during the initial year of operation, the Traction Power demand at the 4 TSS's, varies between 32.2 MVA to 43.1 MVA. Hence, 2 Traction Transformers, each of 40 MVA rating (ONAN) with a provision for forced air cooling (ONAF) may be installed at each Substation. One Transformer will be feeding the load while the other will remain as 100% hot standby. When forced air cooling is brought into action, as and when required, the transformers can be made to deliver about 60 MVA. This means that till such a time the total Traction Power demand at any TSS is less than 60 MVA, the arrangement would be adequate. However, when the total Traction Power demand exceeds 60 MVA, it would be necessary to install one more transformer 40/60 MVA (ONAN/ONAF) and one transformer will feed to each side of the TSS, so that the total demand upto about 80 MVA at each Substation will be met and 50% hot standby will be available. The Substation layout will be designed to cater to the above arrangement. It may be noted that, even when one transformer is delivering 40 MVA to the Traction Overhead System, the proposed copper section of the OHE is adequate to carry the current, since the total current gets distributed between the Up and Down OHEs. It would, however, be necessary to verify the voltage drop at the farthest point of feed from the Traction Substation. This has to be done at the Detailed Design stage of the Project, by doing a Traction Simulation Study, using a validated computer software.

8.7.2 Sectioning and Paralleling Posts (SP)

In order to segregate the power supply feeds from adjacent substations, Sectioning Posts are provided with a Neutral Section (phase-break) in front of it. In addition, at this location the OHE of Up and Dn tracks are paralleled by means of Interrupter.

8.7.3 Subsectioning and Paralleling Posts (SSP)

At suitable intervals the OHE shall be divided into Sub-sectors by means of insulated overlaps, normally bridged by an Interrupter. In addition, wherever required the OHE of Up and Dn tracks may be paralleled by means of Interrupter.

Tentatively, the following are the locations of SP and SSP

Table 8-23: Location of TSS, SSPs and SPs

Sr. No.	Station	Km	Switching Station
1	New Delhi	3.5	SSP
2	INA	15.5	SSP
3	**Dhaula Kuan**	20.0	**TSS/FP**
4	Mahipalpur	26.5	SSP
5	Cyber City	34.0	SSP
6	Rajiv Chowk	41.5	SP
7	Manesar	54.5	SSP
8	**Panchgaon**	64.0	**TSS/FP**
9	Dharuhera	77.0	SSP
10	BTK	86.0	SP
11	MBIR	101.0	TSS/FP
12	**Rewari**	106.5	**SSP**
13	Bawal	119.0	SSP
14	SNB	126.0	SP
15	**Khairthal**	155.5	**TSS/FP**
16	Alwar	180.0	SSP

8.8. Auxiliary Power Supply Network

8.8.1 General

As explained above, electric power will be required at various stations and at some locations inside the tunnels (between the stations) to cater to

- Station lighting
- Escalators and elevators at stations
- Pumps
- Ventilation fans at stations and/or inside tunnels, in underground sections
- Air conditioning of various functional rooms
- Food-marts, Travellers Requisites shops, ATM's etc in the stations

The estimated power requirement for the various years would be as shown in Table 8-24.

Table 8-24: Power Requirement per TSS

Year	Power requirement (MVA)				
	Dhaula Kuan	Panchgaon	MBIR	Khairtal	Total
2016	18.0	1.2	3.2	2.9	**25.3**
2021	18.0	1.2	3.2	2.9	**25.3**
2031	23.0	2.0	5.0	4.5	**34.5**
2041	23.0	2.0	5.0	4.5	**34.5**

8.8.2 Auxiliary Network

At the 4 proposed Receiving Substation locations, 132 kV or 66 kV power received from the Grid, will be stepped down to 33 kV and distributed along the Corridor, by means of a 33 kV Cable Network. Reliability of electric power at stations is of paramount importance. If there is power failure and as a consequence lighting / elevators / escalators etc stop working, the station will be reduced to a chaotic situation with panic among the commuters, particularly in underground sections. With a view to avoiding such a panic situation, a 33 kV duplicate network, with adequate electric protection arrangements, is proposed, so that even if one set of cables develop a fault, all supplies to all stations will be able to be met with the help of the healthy set of cables.

8.8.3 Rating

Considering that in the horizon year 2041, the Underground Stations will need about 2500 kVA and the elevated stations will need about 500 kVA of electric power, the ratings of the Auxiliary Network and transformers shall be adequately designed.

Tentatively, the 4 Receiving Substations shall each be provided with 2 transformers (132 kV or 66 kV / 33 kV, 3 phase) each of the following ratings

Dhaula Kuan	:	2 x 20 MVA
Panchgaon	:	2 x 20 MVA
MBIR	:	2 x 10 MVA
Khairthal	:	2 x 10 MVA

In stations, 33 kV / 415 V, 3-phase Auxiliary Transformers of the following ratings are proposed.

In Underground Stations	:	2 x 2500 kVA
In Elevated Stations	:	2 x 630 kVA

8.9. Traction Overhead Equipment

8.9.1 Elevated Section

25 kV, pre-sagged simple Flexible Overhead Equipment (OHE) is proposed to be provided in the Elevated Section. This type of equipment extensively used on IR and in Metro Systems in Delhi, is suitable for a maximum operational speed of 160 kmph.

Considering the Traction Power requirements, an OHE System capable of carrying 800 A is recommended. A Cadmium copper messenger wire (65 sq mm) with a hard-drawn grooved contact wire (150 sq mm) is proposed.

In Maintenance Depots and Yards, regulated tramway type equipment (contact wire only) may be selectively used.

8.9.2 Underground Section

In tunnels and stations in the Underground Section, Rigid Overhead Catenary System (ROCS) is proposed to be used. The ROCS includes an aluminium profile (conductor rail) and a copper Contact wire inserted inside the aluminium profile. The aluminium cross-section is about 2200 sq mm and the contact wire is of 150 sq mm copper.

The Conductor rail with the inserted copper contact wire is supported from the tunnel top by means of steel supports and copper-aluminium hanger clamps. Support insulators of Silicon composite insulators are preferred.

8.10. Supervisory Control and Data Acqusition (Scada) System

Computer based Supervisory Control and Data Acquisition System will be provided. An **Energy Control Centre (ECC) will be located at New Delhi and Remote Terminal Units (RTU)** will be located at various controlled stations (such as Substations, Switching Stations, Auxiliary Substations, Depot Control Centres, Station Control Rooms etc), along the alignment. It will be possible to control and monitor the various equipments at these locations, from the ECC. In addition all required data will be collected from these controlled stations and transmitted to the ECC, via an Optical Fibre Cable.

Digital Protection Control System is proposed for providing data acquisition, data processing, overall protection control, interlocking, inter-tripping and monitoring of the entire power supply system.

9. Ventilation and Air Conditioning System

9.1. Introduction

This Chapter covers the Ventilation and Air – conditioning (VAC) system requirements for the underground sections of the proposed DGRA RRTS alignment. It includes the following:

- Station Air-conditioning System
- Ventilation System for station plant rooms (ancillary spaces)
- Station Smoke Management System;
- Tunnel Ventilation System.

9.2. Alignment

The proposed alignment has an underground section of about 39 Kms including 8 underground stations on the main line. The RRTS alignment passes through the heart of the Delhi city with the underground section starting from ISBT (KG) station to near IFFCO Chowk after Cyber City Station on NH-8 in Gurgaon. The inter-station distances vary from 3.5 km to 7.5 km.

9.3. Need For Ventilation And Air-Conditioning

The underground stations of the RRTS Corridor are proposed to be built in a limited or confined space due to the very nature of their placement. A large number of passengers are likely to occupy concourse halls and the platforms, especially during the peak hours. The platform and concourse areas will have a limited access from outside and will not have natural ventilation. It is, therefore, essential to provide forced ventilation in the stations and inside the tunnel for the purpose of:

- supplying fresh air for the physiological needs of passengers and the operating staff;
- Removing body heat, obnoxious odours and harmful gases like carbon dioxide exhaled during breathing;

- Preventing concentration of moisture generated by body sweat and seepage of water in the sub-way;
- Removing large quantity of heat dissipated by the train equipment like traction motors, braking units, compressors mounted below the under frame, lights and fans inside the coaches, A/c units etc.;
- Removing vapour and fumes from the battery units and heat emitted by light fittings, water coolers, Escalators, Fare Gates etc. working in the stations;
- Removing heat from air conditioning plant and power sub-station and other equipment, if provided inside the underground station.

This large quantity of heat generated in underground stations cannot be extracted by simple ventilation especially when the outdoor air temperature and humidity is high during summer and monsoon period respectively in the region of RRTS operation. It is, therefore, essential to provide mechanical cooling in order to remove the heat to the maximum possible extent. In winter months it may not be necessary to cool the ventilating air as the heat generated within the station premises would be sufficient to maintain the comfort requirement.

9.3.1 External Environment Conditions and Weather Data

The design weather data from the ASHRAE handbooks have been used to arrive at the design criteria. Based on the feedback and analysis of the VAC system installed at Delhi Metro, it is suggested that 2% criteria would be acceptable on techno economic reasons.

The outside environment conditions for Delhi as adopted by DMRC are given as:

Summer:	43°C (DB)
	28°C (WB)
Monsoon:	35°C (DB)
	29°C (WB)
Winter:	10°C (DB)
	07°C (WB)

The ambient temperatures of summer and monsoon periods are to be used for the design of the stations air conditioning system. As per experience, heating system for the public systems is not envisaged.

The air pollution of Delhi throughout the year adds new dimension and there is a critical need for maintaining desired Air-Quality (Environmental control) in public places like metro stations. High content of suspended particles, Carbon Mono-oxide, Sulphur Dioxide etc. discharged in the air from moving traffic, industries etc. requires consideration of the provision of appropriate mitigatory measures for air-pollution control in metro stations, while designing the VAC system.

9.3.2 Sub Soil Temperature

The temperature conditions of sub-soil play a vital role in the system design of the underground stations. Sub Soil temperature measurements carried out by DMRC for their Phase – I & Phase – II sections concludes the average subsoil temperature to be about 29°C.

9.4. Internal Design Conditions In Underground Stations

With hot ambient conditions of Delhi during the summer and monsoon months, it is essential to maintain appropriate conditions in the underground stations in order to provide a comfortable and pollution-free environment. The plant capacity and design of VAC system needs to be optimized for the envisaged design conditions in the inside of the proposed stations.

The Indian Standards & Codes, which pertain to office-buildings, commercial centres and other public utility buildings, have no guidelines on temperature standards to be maintained for the underground mass rapid transit systems as yet. The standards used for buildings cannot be applied straightway for the underground spaces, because the patrons will stay for much shorter durations in these underground stations.

The comfort of a person depends on rapidity of dissipation of his body heat, which in turn depends on temperature, humidity and motion of air in contact with the body. Body heat gets dissipated is given out by the process of evaporation, convection and conduction. Evaporation prevails at high temperature. Greater proportion of heat is dissipated by evaporation from the skin, which gets promoted by low humidity of air. The movement of air determines the rate of dissipation of body heat in the form of sensible and latent heat. There are different comfort indices recognized for this purpose. The 'Effective Temperature' criterion was used in selecting the comfort conditions in DMRC metro systems operating in the region. In this criterion comfort is defined as the function of temperature and the air velocity experienced by a person. More recently a new index named RWI (Relative Warmth Index) has been adopted for metro designs worldwide. This index depends upon the transient conditions of the metabolic rate and is evaluated based on the changes to the surrounding ambience of a person in a short period of about 6 to 8 minutes. It is assumed that during this period human body adjusts its metabolic activities. Therefore, in a subway (underground) system where the train headway is expected to be six minutes or less, RWI is the preferred criterion.

9.5. Design Parameters For Vac System

Based on the reasons stated in the previous sections, the following VAC system design parameters are assumed in the present report.

(1) **Outside ambient conditions.**

This is based upon ASHRAE recommended design conditions for 1% criteria as under:

Summer **42.0 DB, 22.4 WB**

Monsoon **32.3 DB, 29.1 WB**

For the DGRA RRTS Underground Corridor it is suggested to use 1% criteria, which is defined as the conditions, when the DB or WB temperatures are likely to exceed for only 1% of the total time.

(2) Inside design conditions:

Platform area -- 27 deg.C at 55% RH

Concourse -- 28 deg.C at 60% RH

(3) Tunnel design conditions

Normal conditions -- Max.DB 40 deg. C

Congested conditions-- Max.DB 45 deg.C

(4) **Minimum fresh air -** 10% or 18 cmh/person
(in station public areas)

9.6. Design Concepts For Vac System

There are various VAC design concepts technically feasible in a subway system that can provide and maintain acceptable subway environment conditions under different requirement and constraints. These are: Open Type; Closed Type; Mid-Tunnel Cooling; Semi Transverse Ventilation; Use of jet fans; use of mid-shafts; platform screen doors etc. An overview of VAC systems in DMRC metro's Phase I & II that have similar climatic behavior and ambient conditions have provided valuable information and key guidelines in deciding VAC concept for DGRA RRTS Underground Corridor.

The design selected by DMRC for their Phase I & II corridors is referred to as the Closed Shaft System and the same is being proposed by DMRC for their Phase III as well.

The closed system concept has been evaluated together with the open system concept. The main difference between the two systems is with Open system all tunnel ventilation shaft dampers are wide open to permit a free exchange of air between the running tunnels and the atmosphere, while in a closed system the ventilation shaft dampers are closed and the tunnel air is re-circulated to the station air conditioning system. For the summer and monsoon design conditions, the enthalpy of the air entering the station air conditioning systems from the track way is considerably less than that of air entering the system from outside. This translates into a reduced air conditioning system capacity and the operating cost.

From the experience of DMRC, for such conditions it can be concluded that in the open shaft system the piston effects will not be sufficient to maintain acceptable conditions inside the tunnel, with the ambient DB Temperature above 33^0C. When the outside temperature is higher than 33^0C the tunnel shafts should be closed to prevent any further exchange of air with atmosphere. The station premises (public area) can be equipped with separate air-conditioning system during the summer and monsoon months to provide acceptable environment for patrons. There shall be provision of Track way Exhaust System (TES) by which platform air can be re-circulated. The train cars reject substantial heat inside subway. When the trains dwell at the stations TES would capture a large portion of heat released by the train air conditioners mounted on the roof tops and under gear heat because of braking, before it is mixed with the platform environment if there are no Platform screen doors.

The train heat generated inside the tunnel sections would be removed by the train's piston effect. It is envisaged that for the outside design conditions, it may not be necessary to provide forced ventilation using Tunnel Ventilations Fans for normal operating conditions. The number of shafts required would be two or more depending on the inter station distances. The two shafts would be at the end of the stations and the remaining shafts, if required, can be built at the mid-tunnel sections for every 1500-2000 meters. This is required to ensure that only one train remains in one ventilation zone, to maintain the desired headway. These end-shafts at the stations also serve as Blast Relief Shafts i.e. the piston pressure is released to the atmosphere before the air-blast reaches the station. All these shafts are connected to the tunnels through dampers. The dampers are kept open where the exchange of air with the atmosphere is permitted (Open system). For the closed system the shaft dampers can be in closed mode and the displaced air is dumped in the adjacent tunnel.

Generally each tunnel ventilation shaft has a Tunnel Ventilation fan room in which there are two fully reversible tunnel ventilation fans (TVF) installed with isolation dampers. These dampers are closed when the fan is not in operation. There is a bypass duct around the fan room, which acts as a pressure relief shaft when open during normal conditions, and enables the flow of air to bypass the TVFs, allowing air exchange between tunnels with flows generated by train movements. Dampers are also used to close the connections to tunnels and nozzles when under different operating conditions. The details for the shaft sizes, airflow exchange with the atmosphere, fan capacities can be estimated in more accurate manner with the help of Computer Simulations during the detailed design stage.

Tunnel Ventilation Fan dampers are normally closed when the fan is not in operation. It will open when the fan is in operation.

Figure 9-1: Tunnel Ventilation Dampers

9.6.1 Track way Exhaust System (TES)

The TES is to be installed in the train ways of each station to directly capture heat rejected by the vehicle propulsion ,braking, auxiliary and air conditioning systems as the train dwells in the station. The TES includes both an under platform exhaust (UPE) duct and an Over-track way (OTE) exhaust duct. The TES uses ducts formed in the under platform void and over the track way. Exhaust intakes are to be located to coincide with the train-borne heat sources.

The Track way Exhaust System (TES) fans will be located in the concourse area on both ends of each RRTS Station. The TES will be of suitable capacity for both ends of the platforms, the capacity will be decided during detailed design stage. Based on the experience of DMRC in Phase –II corridors, three fans of 21cum/sec each for either end of the platform will be suitable. In addition to the fans themselves, the mechanical equipment components for the TES will consist of transitions, sound attenuators and dampers. The connections to tunnels and shafts will be through damper units that may be either electrically or pneumatic actuated.

Figure 9-2: Trackway Exhaust Fan

9.6.2 Tunnel Ventilation Systems (TVS)

The TVS is provided in a Subway system essentially to carry out the following functions:

a) Train Pressure release during normal operation.
b) Removal of heat during congested conditions.
c) Ventilation during maintenance period, if required.
d) Removal of smoke during emergency conditions
e) Maintenance of smoke free evacuation route and provision of adequate fresh air during fire related emergencies.

Figure 9-3: Tunnel Ventilation Fan

There are various operating modes (scenarios) for the Tunnel Ventilation system. These are described as under:

9.6.3 Normal Conditions

Normal condition is when the trains are operating to timetable throughout the system, at prescribed headways and dwell times, within given tolerance. The primary source of ventilation during normal conditions is generated by the movement of trains operating within the system and, in some cases, the track way exhaust system.

During summer and the monsoon seasons, the system will be functioning essentially with the station air conditioning system. The vent shafts to the surface will enable the tunnel heat to be removed due to train movements. The platform air captured by the track way exhaust system shall be cooled and re-circulated. For less severe (i.e. cool) environmental conditions (or in the event of an AC system failure), station air conditioning will not be used and ventilation shafts will be open to atmosphere (open system) with the track way exhaust system operating. For cold conditions the closed system or open system mode may be used, but without any station air conditioning. System heating is achieved by the train heat released into the premises.

9.6.4 Congested Conditions

Congested conditions occur when delays cause disruption to the movement of trains. It is possible that the delays may result in the idling of a train in a tunnel section. Without forced ventilation, excessive tunnel temperatures may result, reduced performance of coach air conditioners that may lead to passenger discomfort.

During congested operations, the tunnel ventilation system is operated to maintain a specific temperature in the vicinity of the car air conditioner condenser coils (i.e. allowing for thermal stratification). The open system congested ventilation shall be via a 'push-pull' effect where tunnel vent fans behind the train are operated in supply and tunnel vent fans ahead of the trains are operated in exhaust mode. Nozzles or booster (jet) fans will be used to direct air into the desired tunnel, if required.

9.6.5 Emergency Conditions

Emergency conditions are when smoke is generated in the tunnel or station track way. In emergency conditions, the tunnel ventilation system would be set to operate to control the movement of smoke and provide a smoke-free path for evacuation of the passengers and for the fire fighting purposes. The method of controlling the smoke is the same as for the open system congested mode. The ventilation system is operated in a 'push-pull' supply and exhaust mode with jet fans or nozzles driving tunnel flows such that the smoke is forced to move in one direction, enabling evacuation to take place in the opposite direction. The maximum allowable temperature in the tunnel evacuation path must not exceed 60°C. The train fire heat release rate is assumed to be 20MW.

9.6.6 Pressure Transients

The movement of trains within the underground system induces unsteady air motion in the tunnels and stations. Together with changes in cross section, this motion of air results in changes in air pressure within trains and for wayside locations. These changes in pressure or 'pressure transients' can be a source of passenger discomfort and can also be harmful to the wayside equipment and structures. Two types of transient phenomenon are generally to be examined.

a) **Portal Entry and Exist Pressure Transients-** As a train enters the portal, passengers will experience a rise in pressure from when the nose enters until the tail enters. After the tail enters the pressure drops. Similarly, as the nose exits a portal, pressure changes are experienced in the train. To minimize the entrance of hot air from the portal the dividing wall should be absent for one train length.

b) **Wayside Pressure Transients-** As trains travel through the system they will pass structures, equipment and patrons on platforms. Equipment would include cross passage doors, lights, dampers, walkways etc. Pressures are positive for the approaching train and negative for retreating trains. Most rapid changes occur with the passage of the train nose and tail. The repetitive nature of these pressures may need to be considered when considering fatigue in the design of equipment.

The detailed analysis to assess the effect of pressure transients will have to be done during the design stage. For the portal entry/exits the effect of higher train speed may pose discomfort to the passengers. Although, based on the recent studies, it is assumed that a design train speed of 120 kmph would not be of major concern. The estimation of Way-side transients during design stage would be necessary to select mechanical strength of the trackside components and fixtures, e.g. false ceilings, light fittings etc. at the platform levels.

9.7. Station Ventilation And Air Conditioning Of Ancillary Spaces

Ancillary spaces such as staff room, equipment plant room, will be mechanically ventilated or air conditioned in accordance with the desired air change rates and temperatures/humidity.

All ancillary areas that require 24-hour air conditioning will be provided with fan-coil units (FCU) and standby AC units. During the revenue hours when the main chilled water system is running the FCU will be used for air-conditioning and in non-revenue hours standby AC units will be operated. Return air grilles will be fitted with washable air filters for the re-circulation of the air.

Where fresh air is required it will be supplied to the indoor unit via a fresh air supply system, complete with filter, common to a group of ancillary areas. The fresh air unit will be located in the VAC plant room and will be time switch controlled with local override. Temperature control will include an alarm setting, which is activated on attaining high temperature.

9.7.1 Station Smoke Management System

The Track way Exhaust and Concourse smoke extract fans will be provided for smoke extract purposes from the public areas and will operate in various modes depending on the location of the fire. The associated supply air-handling units will provide support, to assist in smoke control in the event of a fire in the station. The control of this system in fire mode will be fail-safe. These exhaust fans will be provided with “essential” power supplies, with automatic changeover on loss of supply.

Down stand beams will be provided underneath the ceiling around floor openings for stairs and escalators, so that a smoke reservoir is formed. The smoke will be contained in this reservoir at ceiling level and exhausted to atmosphere. By controlling smoke in this manner, it is possible to maintain a relatively smoke clear layer above human head height and to protect the escape route, giving sufficient time for evacuation. The stations will be designed to accommodate full smoke exhaust volumes and thus prevent the reservoir from completely filling with smoke. To provide an additional barrier against smoke migration, the overall smoke management system would be designed to provide a draught of fresh air through entrances and escape routes, to assist in protecting those routes from smoke.

9.7.2 System Components for VAC

The various components and equipment used in the VAC system are described in the following sections:

9.7.3 Station Air Conditioning

The platform and concourse areas will be air-conditioned using supply 'air handling units' located in Environmental Control plant rooms throughout the station. Each platform will be served by at least two separate air handling units (AHUs) with the distribution system combined along each platform to ensure coverage of all areas in the event of single equipment failure.

Figure 9-4: Air Handling Unit

These air conditioning systems mix return air with a desired quantity of outside air. The outside air requirement is based on occupancy, with a minimum of 5 litres per second per person or 10% of circulated air volume, whichever is the greater. The provision of free cooling by a simple two-position economizer control system will be included, with the use of enthalpy sensors to determine the benefits of using return air or outside air. This will signal the control system to operate dampers between minimum and full fresh air, so as to minimize the enthalpy reduction needed to be achieved by the cooling coil. This mixture of outside and return air is then filtered by means of suitable filters and then cooled by a cooling coil before being distributed as supply air via high level insulated ductwork to diffusers, discharging the air into the serviced space in a controlled way to minimize draughts. Return air to the platform area is extracted via the track way exhaust system and either returned to the AHUs or exhausted as required.

Water-cooled chiller units with screw compressors are recommended to be provided at each station, which are energy efficient. These units can be installed in a chiller plant room at surface level or in the underground premises. Based on the initial concept design, the estimated capacity for a typical station would be around 900 TR, without Platform Screen doors (PSD). Hence four units of 300 TR (including one stand-bye) may be required for full system capacity (i.e design PHPDT traffic requirement).

If the Platform Screen Doors are introduced there will be reduction in Air-conditioning equipment and substantial saving in Energy and it is safer for public. Based on the initial concept design, the estimated capacity for a typical station would be around 550 TR, if Platform Screen doors (PSD) are considered. Hence three units of 250 TR (including one stand-bye) may be required for full system capacity (i.e design PHPDT traffic requirement).

During the detail design stage this estimated capacity might get marginally changed for individual station depending on the heat loads.

Figure 9-5: Chiller Plant Room

In view of the temperate outdoor conditions, alternatively it is possible to utilize air-cooled chiller units, which can save large amount of water requirement. The air-cooled chillers should be equipped with screw compressors so that they can be operated at a very less load with high efficiency. These units also eliminate requirement of condenser water circuits including pumps, cooling towers and make up water plants, but are less efficient as compared to the water-cooled- units. During detailed designing stage if the provision of dehumidifier is felt necessary, the same need to be provided.

9.8. Tunnel Ventilation System

As described earlier tunnel ventilation fans will be installed in each of the fan rooms near vent shafts. There shall be three fans in a fan room at each end of the station. The fan capacity depends on the inter-station distances and may vary from 75m^3/s to 100m^3/s. The exact capacity will be obtained through the simulation during detailed design stage. If necessary, nozzle type structures made up of concrete or steel may also be constructed to achieve desired airflow and air velocity in the tunnel sections. Alternatively, booster fans (jet fans) may be installed to direct the flow in the desired direction. These fans may also be used for emergency ventilation at crossover locations and will be required at the end of the portal to direct the airflow. To minimize the entrance of hot air from the portal the dividing wall should be absent for one train length.

A comprehensive remote control and monitoring system for operation and control of tunnel ventilation system will be installed. The alarm and status signals from the equipment will be transmitted to operations control centres (OCC) through SCADA. The activation command for a group of equipment will be initiated from OCC by the controller. There shall be a mode table defining sequence of equipment operation for each event or scenario.

Space Requirement for VAC System

The station air conditioning and tunnel ventilation equipment plant room are normally located at each end of the concourse for the two level stations. The approximate area for air handling equipment room would be 700 sq m and for tunnel ventilation fan room would be 600 sq. m respectively at each end of the station. The tunnel vent shafts of approximately 25-30 sq. m area will be constructed at each end of the stations. There shall be supply shaft and exhaust shafts at the stations of similar dimensions. For the underground stations with large inter station distances there may be necessity of constructing mid tunnel shaft.

Generally mid shaft is required if the inter station distance is more than 1.5 Kms for 2.5 minute headway. The requirement of mid-tunnel shaft can be minimized, if not eliminated, if in-bound dumping is increased and train AC's work up to 50^0C. Alternatively, the adjacent station's end shaft will be provided with fans of higher pressure since thrust required will be more. We can reduce the pressure (and also fan power requirement) if booster fans are used, preferred in cut-cover tunnel sections. Computer simulation during design stage would tell about the need of mid tunnel cooling dumping.

9.9. Control And Monitoring Facilities

For the underground stations the control and monitoring of station services and systems such as Station air-conditioning , ventilation of ancillary areas, tunnel ventilation, Electrical Panels, lighting, pumping systems, lifts & Escalators etc. shall be performed at Station Control Room (SCR). However, the operation and control of Tunnel Ventilation as well as Smoke Management system will normally be done through Operation Control Centre (OCC). All these systems shall be equipped with automatic, manual, local and remote operation modes. The alarms and signals from the equipment at stations shall be transmitted to the OCC via communication network (such as FOTS)

There shall be an Auxiliary Power Controller at OCC who will be monitoring these services and systems. The command signals will be initiated at OCC and relayed up to the relevant equipment for operation. The feedback signal is received through SCADA whether the command is implemented or not. The control from OCC is generally performed using 'Mode Tables' for each system. This table defines the sequence of the desired equipment that needs to be operated based on the event. The abnormal conditions such as train congestion, emergency, fire in subway would be detected by various components and the emergency response thereto will be activated based on the mode tables. In the event that remote control is not possible due to any reason, the local control via SCR would be performed. The OCC will also be used for logging the alarm status, fault occurrences, and other maintenance related data for the above systems.

9.10. Codes and Standards

The concept VAC design is guided by the following codes and standards:

(a) SDEH- Subway Environment Design Handbook.

(b) ASHRAE- Handbook, current series.

(c)- CIBSE- relevant document.

(d) NFPA- 130, 2003 edition

10. Depots

10.1. Introduction

The train configuration envisaged for catering to the traffic demand on the project corridor is given in Table 10-1.

Table 10-1: Train Formation

Type of Car	
DMC	Driving Motor Car
MC	Motor Car
TC	Trailer Car
Train Composition	
6-Cars	DMC-TC-MC-MC-TC-DMC
9-Cars	DMC-TC-MC-MC-TC-MC-MC-TC-DMC

10.2. Approach to Maintenance

Considering the overall route length of 180 Kms and to minimise light (empty) running, three depots – one main depot at MBIR and two satellite depots at Delhi and Alwar – are planned and the facilities at each of them are as described hereinafter.

MBIR Depot-cum-Workshop shall cater to stabling of trains and other stocks, their cleaning, washing, wheel reprofiling minor and major preventive maintenance schedules and also corrective maintenance.

The layout shall primarily include

- Stabling shed, Inspection shed and maintenance workshop
- Coach washing line
- Operational ,functional and safety requirements
- Administrative offices for Depot
- Ancillary buildings for depot and corridor related maintenance
- Power supply and distribution systems
- Water supply, drainage and other utilities

The satellite depots at Delhi and Alwar shall cater to terminal stabling and related maintenance.

Their layout shall basically cover

- Stabling shed and Inspection shed
- Coach washing line
- Operational ,functional and safety requirements
- Depot Manager's Office
- Power ,Water supply, drainage and other utilities

One line in the inspection shed shall be designed to handle coach lifting in case of emergency.

Table 10-2: Year - Wise Train Operation Plan and Kms earned (Adopted from 'Train Operation Plan')

Year	2016			2021			2031			2041		
	No. of Trains		Kms earned	No. of Trains		Kms earned	No. of Trains		Kms earned	No. of Trains		Kms earned
	Up	Down		Up	Down		Up	Dn		Up	Down	
Total	112	112	**40,320**	134	134	**48,240**	112	112	**40,320**	134	134	**48,960**
No. Coaches per train			6			6			9			9
Total Kms earned per day			2,41,920			2,89,440			3,62,880			4,40,640
Total No. of Coaches			264			318			396			477
Kms/coach / day*			**916**			**910**			**916**			**924**

***** Average utilization of 900 Kms per day is taken for maintenance planning purposes.

10.2.1 Maintenance Philosophy

Salient features of maintenance philosophy are:

- Monitoring the performance of equipment by keeping track of key parameters. The idea behind such attempt is to evolve need based maintenance regime to evaluate and redefine the preventive maintenance schedules
- Increasing emphasis on automated and mechanised procedures and processes to minimise manual labour
- Multi-skilling of staff to ensure optimum productivity
- Energy conservation in all areas of maintenance
- To strive zero defect in service

10.2.2 Rolling Stock Maintenance Needs

The following maintenance schedules have been envisaged for conceptual design of depots assuming a utilisation of 900 km per day per rake in use. (see Table 10-3)

Table 10-3: Rolling stock maintenance schedule.

Type of Schedule	Interval*	Work Content	Location
Daily	Daily	Check on the train condition and function after service completion. Internal cleaning / mopping of floor and walls with vacuum cleaner.	Stabling Shed
'A'-Check	5,000 Km 6-days	Detailed inspection and testing of systems, replacement of oils & lubricants and consumables	Inspection Shed
'B'-Check	15,000 Km 15-18 days	Detailed inspection of 'A' type tasks plus items at multiples of 15,000 Km ('B' type tasks),	Inspection Shed
'C'-Check	2,10,000 8 months	All B-check items plus detailed inspection of the bogies and undergear.	Workshop
Intermediate Overhaul (IOH)	4,20,000 Km 16 months	Check and testing of all sub-assemblies (Electrical + Mechanical). Replacement of parts and rectification, trial run	Workshop
Periodical Overhaul (POH)	8,40,000 Km 3 – 3.5 years	Dismantling of all sub-assemblies, bogies, suspension system, traction motor, gear, control equipment, air-conditioning units etc. Checking repair and replacement as necessary. Inspection and trial	Workshop

*Indicative as kilometerage is the driver

Cleanliness of the trains is essential for maintaining a clean look and comfort of passengers.

Table 10-4: Cleaning and Washing Needs of Rolling Stock

S.No.	Type of Attention	Frequency	Time Required	Location
1.	Dry cleaning of interiors	Daily	2 hours	Stabling Shed
2.	External Washing of Coaches	3 days*	10 minutes	Automatic Washing Plant
3.	Thorough Washing of Coaches	30 days	3 hours	Manual Washing Plant

***** Can be revised to 1 or 2 days if situation warrants

10.2.3 Planning of Maintenance Facilities Set up

The projected traffic and requirement of coaches upto the year 2041 are shown below (adopted from 'Train Operation Plan').

Table 10-5: Coach Requirement

Year	PHPDT (Sectional Load)	No.of Coaches	Coach/Rake capacity	Frequency Mins.	Turn Round Time (Mins.)	No. of Rakes /coaches Reqd	10% extra For POH *	Total No.of Coaches Required
2016	13000	6	226/1356	6.0	240	40/240	24	264
2021	15500	6	226/1356	5.0	240	48/288	30	318
2031	21700	9	226/2034	6.0	240	40/360	36	396
2041	25700	9	226/2034	5.0	240	48/432	45	477

Table 10-6: Stabling Line Requirements

Year	No. of rakes in service	Requirement of Stabling Lines at		
		Delhi	MBIR	Alwar
2016$	44*	8	15	8
2021$	53*	8	15	8
2031	44**	15	30	15
2041	53**	15	30	15

* 6-coach unit **9-coach unit $ 2 rakes on each line

Total number of stabling lines (location-wise) varies depending on the land availability at terminal ends and the actual rake links. Further details will be elaborated and worked out at DPR stage.

Table 10-7: Inspection Line Requirements

Year	No. of rakes in service	Requirement of Inspection Lines at		
		Delhi	MBIR	Alwar
2016$	44*	1	3	1
2021$	53*	1	3	1
2031	44**	1	6	1
2041	53**	1	6	1

* 6-coach unit **9-coach unit $ 2 rakes on each line

Table 10-8: Workshop Line Requirements

Year	No. of rakes/coaches under repair	Requirement of Workshop Lines at		
		Delhi*	MBIR	Alwar*
2016	4/24	1	4	1
2021	5/30	1	5	1
2031	4/36	1	5	1
2041	5/45	1	5	1

***** One workshop line of 3 coaches for emergency attention with limited facilities.

Table 10-9: Depot-wise Requirement of Maintenance Lines

Year	Delhi				Alwar				MBIR				Total			
	CWL	SBL	IPL	WSL	CWL	SBL	IPL	WSL	CWL	SBL	IPL	WSL	CWL	SBL	IPL	WSL
2016	1	8	1	1	1	8	1	1	1	15	3	4	3	31	5	6
2021	1	8	1	1	1	8	1	1	1	15	3	5	3	31	5	7
2031	1	15	1	1	1	15	1	1	1	30	6	5	3	60	8	7
2041	1	15	1	1	1	15	1	1	1	30	6	5	3	60	8	7

CWL: Coach washing Line SBL: Stabling Line IPL: Inspection Line WSL: Workshop Line

10.3. Design of Depot Facilities & Workshop

10.3.1 Introduction

The maintenance facilities for the Delhi-Gurgaon-Rewari-Alwar RRTS project are proposed at the following locations and the facilities proposed are in tune with the maintenance philosophy indicated in this document.

- A Depot-cum-Central Workshop at MBIR
- A Satellite Depot at Delhi
- A Satellite Depot at Alwar

10.3.2 Depot-cum-Central Workshop at MBIR

MBIR Depot-cum-Central Workshop shall be the base workshop for the maintenance of all the rolling stock of the project and accordingly shall have necessary facilities for the same.

The conceptual design envisages the following infrastructure and equipment.

- Stabling Lines for stabling the rakes during non-working hours
- Inspection Lines for inspection of the various sub-systems of the rolling stock at stipulated intervals
- Workshop Lines with facilities for lifting the coaches for heavy repairs and major overhauls.
- Automatic Coach Washing line for external washing of coaches
- Turning system for DMC (Driving Motor Car)
- Facilities for infrastructure maintenance of the depot
- Test Track
- Machinery and Plant
- Lifting Equipment
- Accident Relief and Rescue equipment
- Power supply and distribution arrangements
- Dedicated Service Sections for overhauling and Testing of sub-systems
- General and Special Purpose Tools
- Crew management arrangements
- General store for procurement and recoupment of spares for maintenance
- Material Handling facilities
- Water recycling and conservation facilities
- Staff amenities.
- Administrative offices
- Operating Control Centre and Depot Control Centre
- Training Facilities.
- Effluent Treatments Plant
- Security and access systems
- Fire Fighting Facilities within the depot
- Service Roads and Paths
- Waste Collection and Disposal Systems

10.3.3 Satellite Depots at Delhi and Alwar

These depots shall cater to the immediate operational needs at the terminal ends and shall effectively reduce the need for empty running of trains for originating at terminals. The depots shall hence have necessary facilities for basic maintenance like washing and light repair schedules. These depots shall also have facilities for emergency lifting of coaches should the need arise.

The facilities in these depots shall be limited to

- Stabling Lines for stabling the rakes during non-working hours
- Inspection Lines for inspection of the various sub-systems of the rolling stock at stipulated intervals
- Emergency Workshop Line with facilities for lifting coaches for heavy repairs
- Automatic Coach Washing line for external washing of coaches
- General and Special Purpose Tools
- Crew management requirements
- Under-floor Wheel Lathe
- Material Handling facilities
- Lifting Equipment
- Accident Relief Equipment(Minor)
- Fire Fighting Facilities within the depot
- Stabling Manager's Office
- Water recycling and conservation facilities
- Staff amenities
- Security and access systems
- Waste Collection and Disposal Systems

The satellite depots shall be supported by the Central Workshop for supply of overhauled unit-exchange spares and also to handle heavy repairs as and when needed.

All the depots shall be Eco-friendly and shall be designed to have

- Potable water treatment and distribution
- Rain water harvesting
- Water recycling to minimise fresh water consumption
- Effluent Treatment plant of required capacity
- Landscaping with greenery

Table 10-10: Depot-wise Requirements of Machinery and Plant

S.No.	Description of equipment	Qty. Required at		
		Delhi	Alwar	MBIR
1.	Underfloor Wheel Lathe	1	1	1
2.	25/5-t EOT with lifting tackles & tools	-	-	4

S.No.	Description of equipment	Qty. Required at		
		Delhi	Alwar	MBIR
3.	EOT 2-T with lifting tackles	1	1	2
4.	10/2 EOT with lifting tackles	-	-	1
5.	3-T EOT	-	-	1
6.	15-t mobile jacks – set of 4	-	-	12
7.	25-t mobile jacks – set of 4	1	1	2
8.	Hydraulic Rerailing equipment	-	-	1
9.	Minor Rerailing Equipment	1	1	1
10.	Auto washing plant for coaches	1	1	1
11.	Simulator	-	-	1
12.	Bogie wash plant	-	-	1
13.	Bogie test stand	-	-	1
14.	Work lift platform	2	2	8
15.	Mobile guided work lift platform	4	4	6
16.	Elec.bogie tractor for pulling cars & bogies	-	-	2
17.	Chemical cleaning tanks & Ultrasonic cleaning tanks	-	-	4
18.	Screw type air compressor $30M^3$ per minute	1	1	2
19.	Bogie Turntable	-	-	12
20.	RB cleaning plant	-	-	1
21.	Axle Box Cleaning Plant	-	-	1
22.	HP washing pump for front & rear end cleaning of coaches	1	1	1
23.	Shot Blaster	-	-	1
24.	Paint booth for small parts	-	-	1
25.	Axle shaft inspection equipment(UTS,DP and MPI)	-	-	2
26.	Induction Heater	-	-	1
27.	Oven for motors	-	-	1
28.	Battery Charger	1	1	2

S.No.	Description of equipment	Qty. Required at		
		Delhi	Alwar	MBIR
29.	MIG/MAG welding set (mobile-400amps)	-	-	2
30.	Manual Metal Arc Welding Plant	1	1	6
31.	Fork lift truck 3-T	1	1	4
32.	Pallet truck	2	2	6
33.	Shunting Locomotive	-	-	2
34.	Road Lorry 10-T	-	-	2
35.	Pickup van	-	-	2
36.	Vertical Turret Lathe	-	-	1
37.	Hyd. Wheel press 500-T	-	-	1
38.	CNC surface wheel lathe	-	-	1
39.	CNC axle turning/burnishing lathe	-	-	1
40.	Damper Testing Machine			1
41.	Spring testing machine			1
42.	Filter Cleaning Plant			1
43.	Flat wagon	-	-	2
44.	Self propelled tower wagon	1	1	1
45.	Self-Propelled Accident Relief Train (2/3-coah)	-	-	1
46.	Fuelling Installation	-	-	1
47.	Carbody Stands (set of 4) for coaches	2	2	12
48.	Carbody Stands (set of 4) for other vehicles	1	1	2
49.	10-T Goliath Crane	-	-	1
50.	Industrial Vac. Sweeper	1	1	2
51.	Spl.Jigs & fixtures	$	$	$
52.	Elec.& pneumatic tools	$	$	$
53.	Measuring & Testing equipment	$	$	$
54.	Hand tools and Spl. tools	$	$	$

S.No.	Description of equipment	Qty. Required at		
		Delhi	Alwar	MBIR
55.	Mobile safety steps	$	$	$
56.	Storage racks	$	$	$
57.	Industrial furniture	$	$	$
58.	Office furniture	$	$	$
59.	Canteen Equipment	$	$	$
60.	Dormitory furniture & equipment	$	$	$
61	Training Aids	$	$	$
62	Misc. Office equipment	-	-	$

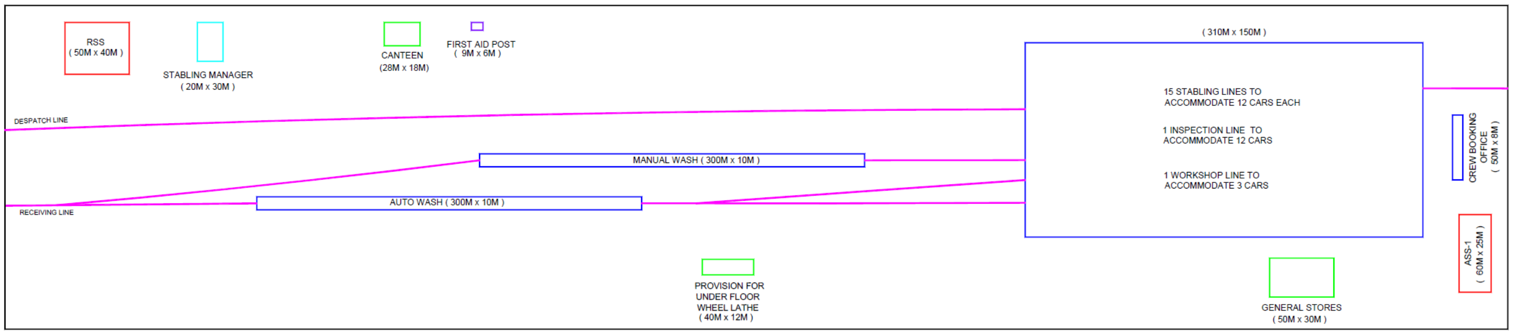
$ Quantity as required.

The tentative location of satellite depot in Delhi near Sari Kale Khan is shown in the Figure 10-1. Conceptual Layouts of the proposed satellite depot and central depot cum workshop are shown in the schematic diagrams in Figure 10-2.

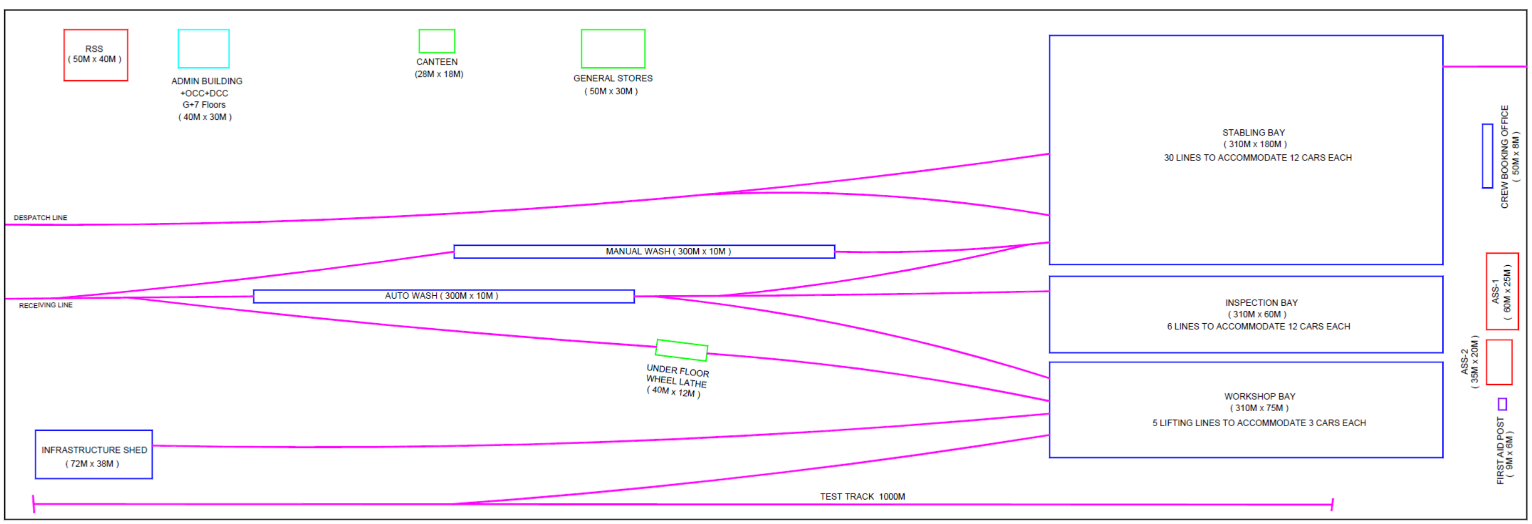
Figure 10-1: Sarai Kale Khan Depot location

Figure 10-2: Typical Depot Layout

CONCEPTUAL LAYOUT OF SATELITE DEPOT
(INDICATIVE ONLY - NOT TO SCALE)
DEPOT AREA : 1200M x 250M = 30 Hectares.



CONCEPTUAL LAYOUT OF DEPOT - CUM - WORKSHOP
(INDICATIVE ONLY - NOT TO SCALE)
DEPOT AREA : 1200M x 400M = 48 Hectares.



11. Cost Estimates

11.1. INTRODUCTION

Project Cost estimates for the RRTS Delhi-Gurgaon-Rewari-Alwar corridor as mentioned below have been prepared covering civil, electrical, signaling and telecommunication works, rolling stock, environmental protection, rehabilitation, considering 25 kV AC traction at January 2012 price level, both for Capital and Operation & Maintenance costs.

While preparing cost estimates, various items have generally been grouped under three major heads on the basis of:-

- Route km length of alignment
- No. of units of that item
- Item being independent entity

All items related with alignment, whether in underground or elevated or at grade construction, permanent way OHE, signaling and telecommunication, have been estimated on rate per route km/km basis. Route km cost for underground alignment construction, excludes station lengths. Station lengths (320m) have to be done by tunneling technique. The rates adopted for underground stations include cost of civil structures and architectural finishes. Similarly, cost of elevated and at grade stations includes civil work for station structures, architectural finishes, platform roofing, etc. Provisions for electrical and mechanical works, air conditioning, lifts, escalators, etc, have been worked out separately. These rates do not include cost of permanent way, O.H.E., power supply, signalling and telecommunication, automatic fare collection (AFC) installations, for which separate provisions have been made in the cost estimates. Similarly, for other items like Rolling stock, Traction & Power, tunnel ventilation, etc, costs have been summed up separately. In remaining items, viz. land, utility diversions, rehabilitation, etc the costs have been assessed on the basis of each item taken as an independent entity.

The overall Capital Cost for the corridor at January 2012 price level works out to Rs.25150 crores including the cost of rolling stock for the induced traffic, excluding applicable Taxes & Duties but including cost of land. Taxes and duties have been added @20% of the cost (excluding land cost) for working out the financial viability. The base rates of Delhi Metro Phase III estimate of January 2011 have been adopted, which have been suitably modified for the RRTS infrastructure and have been escalated further for one year@ 5% per annum.

Details and methodology of arriving at these costs are discussed in the following paragraphs.

11.2. Civil Engineering Works

Land requirements have been kept to the barest minimum and worked out on area basis. Acquisition of private land has been minimized as far as possible.

For underground 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 road verge, side of roads and wherever, this is outside the road alignment, minimum land area about 20m wide is proposed for acquisition for the piers and the service road. Land will be required at stations locations.

Cost of Govt. land is based on the rate presently being charged by the concerned authorities, such as L&DO, MCD, DDA, etc. and circle rates for the rest of the areas.

Provision for cost of land required for resettlement and rehabilitation has been made in the cost estimates.

In addition to the lands required permanently, some areas of land (mainly Govt.) are proposed to be taken over temporarily for construction depots.

Details of the lands with their costs have been shown state-wise in the estimates.

10.2.1 Formation and Alignment

(i) **Underground section:** In the underground section work is proposed to be done by Tunnel Boring Machines. Rates adopted for work to be done by T.B.M. are based on DPR cost of similar works in Phase-III DMRC, 2011, duly updated to

January 2012 price level. Cost of mid section ventilation shafts wherever needed, has also been included.

(ii) **Elevated section:** A good portion of alignment is proposed with elevated viaduct and the rates adopted are based on the DPR cost for these works of Phase-III DMRC MRTS, duly updated to January 2012 price level.

(iii) An important Bridge over river Sahibi is required to be provided. Provision for the same has been made.

10.2.2 Stations

(i) Underground Stations: In the underground alignment, station lengths have to be done by cut and cover or NATM. Rate proposed for stations (length 320m) includes cost of station structures, platforms, architectural finishes, etc. and provisions for electrical and mechanical works, V.A.C., Lifts and Escalators etc., have been made separately. Provisions for O.H.E., P. Way, Signalling and Telecommunication, Automatic fare collection installations, etc. have also been summed up in the cost estimates. Rates are based on the DPR cost of similar works in Phase-III DMRC MRTS duly modified for station lengths updated to the price level of January 2012, wherever required. The cost of underground station has been increased by 40% due to the increase in platform length in case of RRTS which will be 320 meters.

(ii) Elevated Stations: Rates adopted for elevated stations cover works of stations structures, platforms, architectural finishes, covering, etc. Provisions for Electrical and Mechanical works have been made separately. Also provision for Lifts and Escalators, Viaduct, P. Way, O.H.E., Signalling & Telecommunication works, Automatic fare collection installation, etc. have been summed up in the cost estimates. The cost of Elevated station has been increased by 60% for the increase in the cost on account of increase in the length of stations. The costs of Terminal stations have been taken to include additional facilities required at these stations.

11.3. Permanent Way

For underground and elevated alignment ballastless track and for depot, ballasted track is proposed. Rates adopted are based on the DPR cost of similar works in Phase-III DMRC MRTS duly updated to the price level of January 2012,

11.4. Utility Diversions, Environmental Protection, Miscellaneous Other Works

Provisions have been made to cover the cost of utility diversions, miscellaneous road works involved, road diversions, road signages etc. and environmental protection works on lump sum basis.

11.5. Rehabilitation and Resettlement

Provisions have been made on fair assessment basis, to cover cost of relocation of Jhuggies, Shops, residential houses on private land etc.

Provision for barracks for CISF including security equipment and Quarters for O&M staff has been made in the cost estimates.

11.6. Traction and Power Supply

Provision has been made to cover the cost of O.H.E., Auxiliary sub stations, receiving substations, service connection charges, SCADA and miscellaneous items, on route km basis separately for underground alignment, elevated and at-grade section as the requirements are different and costs are more for underground section.

Provisions towards cost of lifts, escalators for underground and elevated stations have been made in the cost estimates. Rates are based on the DPR cost of similar works in Phase-III DMRC MRTS duly updated to the price level of January 2012. Provision for mid section shaft is made separately.

11.7. Signalling And Telecommunication Works

Rates are based on the DPR cost of similar works in Phase-III DMRC MRTS duly updated to the price level of January 2012. These rates include escalation during manufacturing and supply of equipment and their installation at site. Lump sum Cost of Platform Screens Doors (PSD) for the underground stations has also been added in the estimate.

Automatic Fare Collection

Adopted rates are based on the DPR cost of similar works in Phase-III DMRC MRTS duly updated to the price level of January 2012

11.8. Rolling Stock

Adopted rates are based on the DPR cost of similar works in Phase-III DMRC MRTS and DAMEL rolling stock cost duly updated to the price level of January 2012 considering likely increase due to increase in coach dimensions (24mx3.66m) and the operating speed.

11.9. General Charges and Contingencies

Provision @3% has been made towards general charges on all items, except cost of land, which also includes the charges towards Detailed Design Charges (DDC), etc. Provision for contingencies @3% has been made on all items including general charges.

11.10. Capital Cost

The overall Capital cost for these corridors estimated at January 2012 price level, based on the above considerations works out to Rs.25150/- crores.

Table 11-1 shows the Cost Break up for the RRTS corridor

Table 11-1: Cost Break up

S.No.	Item	Unit	Rate based on DMRC Rates of Ph-III of Jan. 2011 escalated @5% for 2012 (in Crore)	Quantity	Amount (in Crore)
1.0	**Land**				
1.1	Land in Delhi State required for underground stations for integration with DMRC, RRTS and Northern Railway; exit and entry for underground station, ventilation shafts and Depot at Sarai Kalekhan.	Hect.	30.00	41.00	1230.00

S.No.	Item	Unit	Rate based on DMRC Rates of Ph-III of Jan. 2011 escalated @5% for 2012 (in Crore)	Quantity	Amount (in Crore)
1.2	Land in Haryana required for elevated station including TOD elevated section between Cyber City and Bawal and Depot at MBIR.	Hect.	0.58	897.00	520.00
1.3	Land in Rajasthan required for elevated station with TOD, elevated station between Bawal-SNB to Alwar and Depot and Alwar.	Hect.	0.31	480.00	149.00
1.4	Temporary land for casting yard, working spares.	Hect.	0.50	225.00	113.00
	Sub Total (1.0)				**2012.00**
2.0	**Alignment and Formation**				
2.1	Underground section - Tunneling by TBM	R. Km	166.00	36.44	6049.04
	Elevated viaduct section	R. Km	32.55	141.00	4589.55
	Special span	R. Km	31.00	1.00	31.00
	Civil Work for mid section ventilation shaft	Each	3.00	20.00	60.00
	Sub Total (2.0)				**10729.59**
3.0	**Important Bridges**				
	Length of Sahibi River = 0.700 km	Nos.	30.00	1.00	30.00
	Sub Total (3.0)				**30.00**
4.0	**Station Buildings;**				
4.1 (a)	Underground Station	Each	178.24	7.00	1248.00
(b)	Underground Terminal Station	Each	250.00	1.00	250.00
4.2	Elevated Station (including finishes)				
(a)	Way side station	Each	37.80	9.00	340.20
(b)	Terminal station	Each	40.32	2.00	80.64

S.No.	Item	Unit	Rate based on DMRC Rates of Ph-III of Jan. 2011 escalated @5% for 2012 (in Crore)	Quantity	Amount (in Crore)
4.3	Interchange facilities at interchange station viz ISBT, New Delhi, Sarai Kale Khan, Dhaula Kuan, Mahipalpur, Cyber City & IFFCO Chowk	Each	10.00	7.00	70.00
	Sub Total (4.0)				**1988.84**
5.0	**E & M Works**				
5.1	Underground station (E&M, Lifts, Escalators, DG Sets, UPS, TVS, ECS etc.)	Each	58.00	8.00	464.00
5.2	Elevated station (E&M, Lifts, Escalators, DG Sets etc.)	Each	6.86	11.00	75.00
5.3	Mid section ventilation shafts	Each	6.00	20.00	120.00
	Sub Total (5.0)				**659.00**
6.0	**Depot**				
	Depot of Sarai Kalekhan, MBIR and Alwar (including Civil Works, E&M, P&M, Track works, OHE etc.)	L.S.			200.00
	Sub Total (6.0)				**200.00**
7.0	**Permanent Way**				
	Ballast less/Ballasted Track for elevated, underground and at grade alignment	R. Km	6.80	183.00	1245.00
	Sub Total (7.0)				**1245.00**
8.0	**Traction and Power**				
	Traction and power supply including OHE ASS etc.				
	Underground section	R. Km			
	Elevated & Grade section	R. Km			
	Sub Total (8.0)				**846.00**

S.No.	Item	Unit	Rate based on DMRC Rates of Ph-III of Jan. 2011 escalated @5% for 2012 (in Crore)	Quantity	Amount (in Crore)
9.0	**Signalling and Telecom**				
9.1	Signalling	R. Km	10.22	183.00	1781.00
9.2	Telecom	Each	4.58	19.00	87.00
9.3	Auto Fare Collection				
9.3.1	Underground station	Each	3.11	8.00	25.00
9.3.2	Elevated Station	Each	3.11	11.00	33.00
9.4	PSD at Station	L.S.			20.00
	Sub Total (9.0)				**1946.00**
10.0	**Rolling Stock (BG)**	Each	13.60	264.00	3590.00
	Sub Total (10.0)				**3590.00**
11.0	**Utilities**				
11.1	Misc. utilities, other Civil works, such as median, road signages, Electrical & Telecom utilities.	L.S.			150.00
11.2	Service roads	Km	1.10	70.00	77.00
	Sub Total (11.0)				**227.00**
12.0	R&R including Hutments and road restoration etc.	L.S.			200.00
	Sub Total (12.0)				**200.00**
13.0	Barracks for CISF including security equipments and staff quarters for ORM staff.	L.S.			40.00
	Sub Total (13.0)				**40.00**
14.00	Special noise & vibration reduction treatment	L.S.			**50.00**

S.No.	Item	Unit	Rate based on DMRC Rates of Ph-III of Jan. 2011 escalated @5% for 2012 (in Crore)	Quantity	Amount (in Crore)
	Sub Total (14.0)				**50.00**
15.00	Total of all item except land				21751.43
16.00	General charges including design charges @3% on all items except land.				653.00
17.00	Total including General Charges.				22404.43
18.00	Total cost including of land cost.				24416.43
19.00	Contingencies @3%.				732.00
	Gross Total				**25148.43**

12. Financial Analysis

12.1. Introduction

Full recovery of capital investment from public transport systems has usually remained elusive considering the huge investments required. Thus higher emphasis is given to operational sustainability for this kind of projects. Such capital intensive projects hugely affects the socio economic dynamics at regional level therefore necessity of such projects could be justified through Socio-Economic Cost benefit analysis which is discussed separately in chapter 13 of the Report.

This chapter attempts to estimate the extent of financial viability and operational sustainability of proposed RRTS project. It discusses inputs and estimations related to project cost, means of finance, revenues, and operations cost. The outcome is judged in various scenarios to conclude the analysis.

12.2. Estimations and inputs

The estimations and inputs for financial analysis are discussed further.

12.2.1 Project cost

The summary of project cost used for financial analysis at constant price is as follows;

Table 12-1: Summary of project cost

Particular	Total
Land	2012
Aggregate Project Cost except land	21753
Total Project Cost with Land	23765
General Charges inc. Design (3% on all items except land)	653
Total with General Charges	24418
Contingency on all items at 3%	733
Project Cost with Contingency	**25150**

(Rs. in Crore)

Source: As per Project cost estimates

The above cost does not include taxes on project goods and interest during construction which is taken after phasing as shown next.

Estimated construction period is five years. Construction is expected to start on 1st January, 2012 and end on 31st December 2016. The project cost is escalated further to match with possible price rise at the time of construction. The Interest during construction (IDC) is also added in the above cost. The table below shows the escalated project cost over the five years. The project cost is escalated with 6% pa considering last 6 year CAGR of annual value of Wholesale Price Index published by Government of India.

Table 12-2: Phasing of Project cost with escalation

Construction Phasing	2012	2013	2014	2015	2016	Total
	10%	20%	30%	30%	10%	100%
Land	213	452	719	762	269	**2416**
Aggregate Hard Cost	2306	4888	7772	8239	2911	**26116**
Tax on Project Goods	231	489	777	824	291	**2612**
General Charges including Design Charges	69	147	233	247	87	**783**
Contingencies	78	165	262	277	98	**879**
IDC	24	75	156	242	275	**771**
Total	**2920**	**6215**	**9919**	**10592**	**3931**	**33577**

(Rs. in Crore)
Source: Author's estimations

There would be increase of 34% in the aggregate project cost by the end of the construction period. The applicable combined taxes from Central and State Governments are estimated to be 20% of the total hard cost. The tax rates are adopted on the basis of other DPRs of various metro rail development projects proposed in India. However as per clause 3.3 of the MOU which is signed between MOUD, NCPRB and State Govt. of Delhi (GNCT), Rajasthan, Haryana and Uttar Pradesh, the Central taxes for RRTS project would be considered as interest free subordinate debt while State Govt. Taxes would be waived off/reimbursed. Thus, the above calculation includes only applicable Central taxes which would be paid in instalments during the operation period.

Means of finance for the project are determined later considering the debt repayment capacity of the project. Estimations related to revenue and O&M expenses are discussed further.

12.2.2 Estimations of Revenue

Urban transit projects lead to a number of benefits to users of the system. The benefits are both direct and indirect in nature. Direct benefits include availability of transit service, opportunities for advertising at transit stations, and opportunities to provide products/services through kiosks/outlets at stations. Indirect benefits arise from association with the project through proximity or through significant positive externalities. The following table shows the nature of benefit and their value capturing possibilities.

Table 12-3: Revenue Capture Instruments for different benefits associated with RRTS Project

Nature of Benefit	Revenue Capture Instrument	Status of capture
Direct	• Fare Box • Advertising • License Fees from station assets	Captured in terms of fare, advertisement revenue and license fee from kiosks, stalls and other assets
Proximate	• Increase in business next to stations • Real Estate Development Rights arising from ToD. • Rise in property value around stations	Captured from property development near stations for TOD
Indirect	• Economic Development on the corridor • Less congestion for road users • Improvement in air quality • Availability of more public space • Reduction in use of fossil fuels	Captured from revenue from carbon credits. Cess on VAT in the states also considered.

Source: Author's Analysis

It can be seen in the above table that direct benefits play a major role in revenue generation while indirect benefits are relatively difficult to capture. Capturing indirect benefits often require concerted action not only at the project level but assume the cooperation and action from institutions involved such as local bodies, regional Government and members of the public receiving the indirect benefits. This is so since indirect benefits follow from non-excludability (meaning it is difficult to exclude those who do not pay for receiving the benefits).

The principal source of revenue for the project is fare revenue. However since such revenue would be insufficient for recovery of capital in a project of this magnitude, property development near the stations in the spirit of developing Transit Oriented Development (TOD) is proposed. This income supports the fare income in a significant manner, though is phased over a long period of time given that development will happen along the corridor only gradually. Further, it has been attempted to capture value from proximity benefits through carbon credits.

The sources of revenue for the project are the following: 1) fare box collection 2) Income from TOD 3) advertisement fees, 4) license fees from stalls within the station premises and 5) sale of Carbon Credit (CC). Estimations related to fare box collection is discussed first, to proceed with.

It is hypothetically estimated that commercial operation would start from 1st January, 2017. Revenue is projected for next 30 years.

12.2.3 Fare box collection

Following tables shows passenger traffic forecast upto 2046 with realistic, optimistic and pessimistic scenarios.

Table 12-4: Projected daily traffic

	Daily Traffic (In lakh)				
Scenarios	2016	2021	2031	2041	2046
Realistic	6.99	9.12	12.55	15.10	16.27
Optimistic	8.06	10.38	14.18	16.98	18.30
Pessimistic	5.96	7.78	10.69	12.79	13.78

Source: Traffic Demand Analysis for RRTS

Average trip length is estimated to be as follows;

Table 12-5: Average trip length

Year	2016	2021	2031	2041
Average Trip Length (km)	27.42	25.96	27.69	28.78

Source: Traffic Demand Analysis for RRTS

The average trip length is increasing over time as the passengers are estimated to commute for longer distance. Following are the proposed fares for the project

Table 12-6: Proposed Fares

Slab in km	Fares for 2011 (Rs.)
0-10	15
10-20	20
20-30	25
30-40	33
40-50	42
50-60	51
60-70	60
70-80	69
80-90	78
90-100	87
100-110	96
110-120	106
120-130	115
130-140	124
140-150	133
150-160	142
160-170	151
170-180	160

Source: Author's Estimation

The fares for each km are placed in the Annexure. The above fares are calculated considering four guiding principles which are;

1) **Affordability** to the users
2) **Sustainability** of the system
3) **Competitiveness** with the other modes of transport on the similar route
4) **Flexibility** for revision

A mix of distance based flat and distance based increasing fares are adopted. Following is the comparison of the above fares with other competing transportation facilities as in 2011.

Table 12-7: Fare comparison

	Average fares (Rs. /Pax)							
Stages	DMRC	DTC	IR Third Ac chair	IR Third AC 3T	IR Second Sleeper	RSRTC	HSRTC	RRTS
Base fare	**8**	**5**	-	-	-	-	-	15
0-10	12	5	-	-	-	-	-	15
10-20	16	10	-	-	-	-	-	20
20-30	20	15	-	-	-	23	28	25
30-40			-	-	-	-	-	33
40-50			-	-	-	-	-	42
50-60			-	-	-	45	56	51
60-70			-	-	-	-	-	60
70-80			-	-	-	59	74	69
80-90			-	-	-	-	-	78
90-100			-	-	-	74	93	87
100-110			240*	210	120	-	-	96
110-120			-	210	120	-	-	106
120-130			-	-	-	97	120	115
130-140			-	-	-	-	-	124
140-150			-	-	-	-	-	133
150-160			-	-	-	119	148	142
160-170			-	-	140	-	-	151
170-180			-	-	140	-	-	160

*Source: Fares of different systems and analysis, * Shatabdi rates*

The proposed fares for RRTS are maintained higher than Delhi Metro Rail and DTC buses to discourage shorter or within the city trips. The rates would be slightly higher than the IR's sleeper class and RSRTC but lower than IR's AC chair and 3 tier AC trains and HSRTC. Proposed RRTS could compensate higher rates through faster, frequent and comfortable services in comparison with IR sleeper class and RSRTC buses. All the above transportation systems cater to the middle and long distance trips which is the target passenger segment for RRTS.

The fares for RRTS are revised biennially, indexed with Consumer Price Index (CPI). Wholesale Price Index (WPI) measures inflation at each stage of production while CPI measures inflation only at final stage of production. Thus the CPI is more relevant to the consumer. The proposed formula for fare revision is placed below;

Revised Fare = Base Fare *(100%*% change of Consumer Price Index-10% of efficiency)

The growth rate in fare is estimated to be 7.5% over the projection period based on above formula. The fare box revenue is calculated using fares applicable per passenger according to average trip length. Such fares are applied on the daily passenger traffic.

It is estimated that 60% of the daily commuters would be pass holders. (A scenario of 90% passes holders is also considered towards the end of the chapter to see its impact on viability). Approx 25% concession on fare is taken for the pass holders. Following is the estimated fare box collection.

Table 12-8: Estimated fare revenue

Particular	2017	2021	2031	2041	2046
Daily Passenger (In lakh)	7.37	9.12	12.55	15.10	16.27
Daily pass holders (In Lakh)	4.42	5.47	7.53	9.06	9.76
Daily revenue from Non Pass holders (Rs. Crore)	1.37	2.26	6.40	15.86	22.82
Daily revenue from Pass holders (Rs. Crore)	1.54	2.54	7.20	17.85	25.68
Daily fare box collection (Rs. Crore)	**2.90**	**4.79**	**13.59**	**33.71**	**48.50**
Annual fare box collection (Rs. Crore)	**986**	**1630**	**4622**	**11462**	**16490**

Source: Author's Estimation

Estimations for Transit Oriented Development are discussed further.

12.2.4 Revenue from property development

As discussed earlier, in order to promote Transit Oriented Development (TOD), development of property along the corridor or at nodes is envisaged by acquisition of land in advance. Such development contributes to a compact city and regional development. Commuters travel from homes to workplaces through an integrated transit system (mix of main and feeder transportation systems). It reduces the travel demand in other part of the city as the origin and destinations are located on the same transport corridor. It results into dense city/region/corridor which is a better proposition as far as urban planning is concerned.

TOD property would be developed on the nodes/stations of the proposed RRTS. It would be a mix of office- retail and residential spaces. It is proposed that the Built Up Area (BUA) would be developed by either the RRTS Project Company or through PPP with developers. The BUA is proposed to be given on lease for 90 years against collection of upfront lease rental. A upfront lease rental model is considered superior to continue lease collection due to benefits of (i) upfront revenue that allows early retirement of debt (ii) it relieves the RRTS company from responsibility of maintenance allowing it to focus on its core business and (iii) in case PPP model is adopted, it is more suitable to PPP model as developers would like to exit after construction and sale. Generally the arrangement is considered equivalent as sale and command rates equivalent to sale.

Following table shows proposed TOD on RRTS corridor which would be developed on stations.

Table 12-9: Estimated TOD

Sr. No.	Station Location	BUA (Sq.mtr)		
		Commercial	Residential	Total
1	Panchgaon	519008	0	519008
2	Dharuhera	293216	174496	467712
3	MBIR	1191680	645344	1837024
4	Rewari	672672	226688	899360
5	Bawal	465024	493248	958272
6	BTK	204064	201600	405664
7	SNB	787360	883904	1671264
8	Khairthal	349216	0	349216
9	Alwar	169792	143808	313600
	Total	**4652032**	**2769088**	**7421120**
	Total (in Lakh)	**46.52**	**27.69**	**74.21**

Source: Estimation based on availability of land at different nodes.

It can be seen that the TOD is proposed mostly outside the NCR region. Around 25% of the total BUA is envisaged in proposed MBIR under DMIC followed by SNB station (23%). Around 25% of the total BUA is jointly proposed at Rewari and Bawal stations. Combined proportion of office and retail space in total TOD is 63% while rest is residential development.

It is understood from published sources that in 2010 combined demand for commercial and residential space in NCR was around 10 lakh sq.mtr while supply was around 6 lakh sq.mtr. The demand for 2011 is estimated to be higher than the previous year owing to new surge in the economy post recovery from global recession. Around 80% of the total NCR demand is anticipated from Gurgaon region alone. Considering the above the aggregate real estate demand in NCR and surrounding region for next 15-20 years can be estimated to be around 300-400 lakh sq. mtr. Owing to proposed DMIC, accessibility of Western ports and Industrial development, the Gurgaon demand is likely to spill over the proposed RRTS corridor.

The proposed TOD is estimated to be absorbed in over 20 years after operations. Thus on an average 3.7 lakh sq. mtrs of built up area would available for lease in each year on an average, though actual absorption rates would vary. Considering the significant demand-supply gap in Gurgaon and future scenario for development along this corridor, absorption of high volumes of property could be possible, though the phasing, annual abortion and exhaustion of all volumes as envisaged here would depend of a number of macro economic, regional and location related developments.

12.3. Phasing of construction and lease of BUA

A lag of 1 year is estimated between construction and leasing of BUA. Thus construction is also phased for 20 years. The phasing is described below:

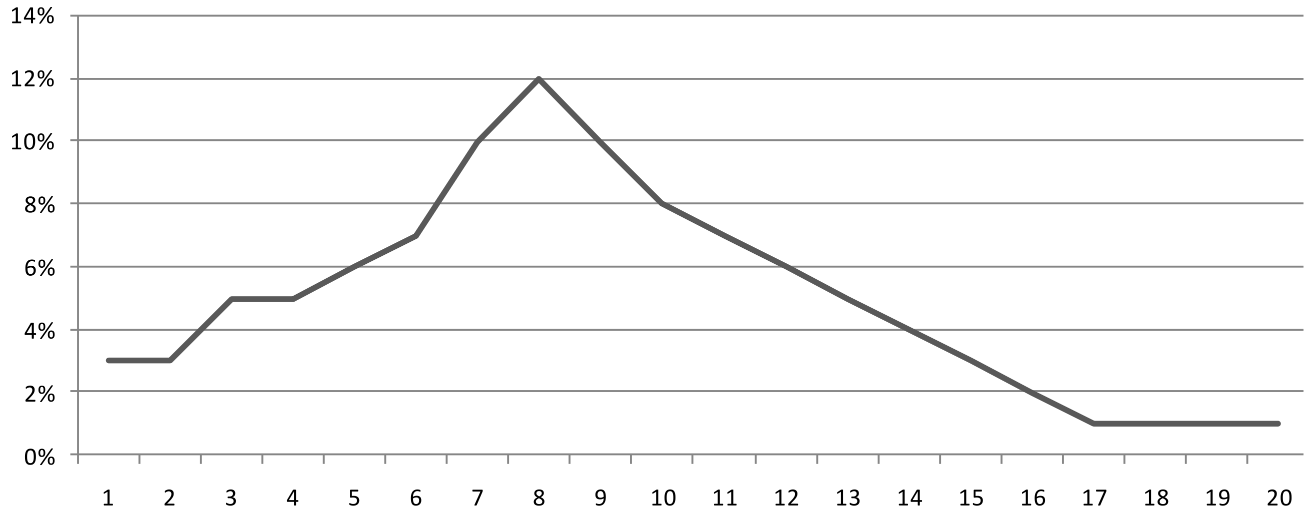


Figure 12-1: Phasing of construction and lease of BUA

Source: Author's Estimation

12.3.1 Construction cost

RRTS stations like Panchgaon, Dharuhera and Alwar would be developed initially followed by MBIR and Rewari. Other stations can be developed in later stage within two years of development of above stations. The development would be cascading with spread over the years. Following is the construction cost estimated for TOD development.

Table 12-10: Estimated construction cost for TOD

Construction of TOD	
Office and retail commercial space	10089
Residential space	6551
Total	**16640**

(Rs. in crore)

Source: Author's Estimation

Per units cost for commercial and residential development for 2011 is taken 11000/sq.mtr and 12000/ sq.mtr respectively. The cost is further escalated at 6%. The average per unit construction cost for 20 years is calculated to be around Rs.21500/sq.mtr and Rs. 23650/sq. mtr for commercial and residential construction respectively.

12.3.2 Lease rates

As the TOD space is proposed to be leased out against upfront payment lease, it is equated with sale prices of property around the TOD stations. This based on information available through published sources confirmed though verification with real estate professionals. Following are the estimated upfront lease rates for the TOD.

Table 12-11: Upfront lease rates for TOD

Station Location	Upfront Lease rates for 2011 (Rs./sq.mtr)	
	Commercial	Residential
Manesar	72397	37385
Panchgaon	57917	29908
Dharuhera	50678	26170
MBIR	60089	31030
Rewari	54297	28039
Bawal	43438	22431
BTK	43438	22431
SNB	65157	33647
Khairthal	28959	14954
Alwar	36198	22431

Source: TOI Property Supplement, JLL Report, Magic Bricks.com, discussions and estimation as discussed.

The sale rates in Manesar are considered to be increased by 10% owing to anticipation of the proposed development. Manesar rates are used as guiding factor for lease rates at other TOD stations whenever published or reliable sources are not available. Rates for some locations are decided based on discussion with local residents with suitable estimations.

The above rates are estimated to increase by 12% over the projection period as the prices along the DMRC corridor have grown by 17% and considering that returns on safer avenues such as Bank Deposits is around 10% pa. Following is the estimated revenue from Property Development.

Table 12-12: Revenue from Upfront lease for Property

Particular	2017	2021	2031	2036	Total
Commercial	1020	3263	5274	3161	**95195**
Residential	268	843	1309	769	**24019**
Total	**1288**	**4105**	**6583**	**3930**	**119213**

Rs. Crore

Source: Author's Estimations

12.3.3 Revenue from Advertisement and Stall licensing

Revenue from advertisement is possible through display space at the stations and on the elevated corridor. Based on standard station design, available advertisement space at each RRTS station and along the corridor has been worked out as follows:

Table 12-13: Estimated Advertisement space

Sr. No	Types of advertisement	Unit	Total
1	Hoardings at Platform Area	Sqm	2380
2	Hoardings at Entry Area	Sqm	684
3	Glow Cubes	*Nos.*	2624
4	Kiosks	*Nos.*	38
5	LED Displays	*Nos.*	76
6	Ad on Trains	Sqm	6143
7	Ad on Tickets / Smart Cards	*Nos. tickets Daily in 2017 in Lakhs*	2.95
8	Hoardings at Parking lots	*Sqm*	389
9	Ad on Lifts	Sqm	291
10	Ad on Escalators	Nos.	32
11	Ad on the elevated corridor	Sqm	26858

Source: Author's Estimations

A second source of revenue is the licensing of stalls, phone booths and ATMS. Following is the aggregate commercial space for all RRTS stations based on estimated demand due to expected foot falls and station design.

Table 12-14:Aggregate commercial space for station premises

Types of Licenses	Area in Sq. mtrs.
Tea and Refreshment Stalls	2336
ATMs	920
Book Stalls	514.8
Juice Stalls	810
Milk And Milk Products Stall	570
Chemists	514.8
Phone Booth	270
Retail Kiosks	920
Parking Lots	19 (Nos)

Source: Author's Estimations

It is estimated that approx. 90% of the total space would remain occupied during the projection period. The licenses would be given for one year to five years at prevailing rentals escalated at 5% pa over 30 years. Following is the proposed unit size and estimated rent for 2011 in Delhi for stall licenses.

Table 12-15: Unit size and estimated rental for stall licenses

Particulars	Size of the stalls (sq.mtr)	Rental Rs. / sq.mtr /month at Delhi
Tea and Refreshment Stalls	40	750
ATMs	20	650
Book Stalls	40	750
Juice stalls	30	675
Milk and Milk products Stalls	30	675
Chemist Stalls	40	750
Phone Booths	10	600
Kiosks	20	625
Parking space (lump sum) Rs. Lakh		10

Source: Author's Estimations

Rates for above space are based on prevailing market prices at nearest Delhi metro station and obtained through discussion with advertisement agencies. These are escalated to 2017 prices. Average growth rate in rates is taken 5% pa. It is estimated that on an average 85% of the total advertisement space would be occupied throughout the projection period.

12.3.4 Revenue from stall licensing within the station premises

Following is the summary of revenue from Advertisement and Licenses.

Table 12-16: Revenue from Advertisement and Licenses

	Particular	2017	2021	2031	2041	2046	Total	Share
A	**Advertisement Revenue**							
1	Hoarding at platform	3.68	13.65	24.44	36.15	41.91	**750.82**	23%
2	Hoardings at Entry Area	0.35	1.29	2.32	3.43	3.98	**71.22**	2%
3	Glow Cubes	0.24	0.88	1.58	2.33	2.71	**48.46**	2%
4	Kiosks	0.01	0.05	0.08	0.12	0.14	**2.52**	0%
5	LED Displays	0.00	0.01	0.01	0.01	0.02	**0.28**	0%
6	Advertisements on Trains	0.78	4.83	12.22	22.10	27.71	**404.44**	13%
7	Advertisement on tickets	6.09	9.81	24.80	44.85	56.23	**829.98**	26%
8	Hoardings at Parking lots	0.64	2.38	4.26	6.30	7.30	**130.85**	4%
9	Advertisement on lifts	0.36	1.33	2.39	3.53	4.10	**73.38**	2%
10	Advertisements on escalators	0.13	0.49	0.88	1.30	1.50	**26.92**	1%
11	Ad on the pillars of elevated corridor	4.25	15.80	28.28	41.84	48.50	**868.82**	27%
	Total	**16.52**	**50.52**	**101.25**	**161.98**	**194.09**	**3207.71**	**100%**
B	**License Income**							
1	Tea And Refreshment Stalls	1.15	2.71	4.86	7.19	8.33	**149.90**	25%
2	ATMs	0.36	1.07	1.91	2.83	3.28	**58.94**	10%
3	Book Stalls	0.15	0.47	0.83	1.23	1.43	**25.58**	4%
4	Juice Stalls	0.40	0.94	1.68	2.49	2.89	**51.97**	8%
5	Milk And Milk Products Stalls	0.28	0.66	1.19	1.75	2.03	**36.57**	6%
6	Chemists	0.20	0.60	1.07	1.58	1.84	**32.98**	5%
7	Phone Booths	0.13	0.31	0.56	0.83	0.96	**17.41**	3%
8	Retail Kiosks	0.36	0.95	1.70	2.52	2.92	**52.47**	9%
9	Parking Lots	2.53	3.32	5.94	8.79	10.19	**185.96**	30%
	Total	**5.57**	**11.03**	**19.74**	**29.21**	**33.87**	**611.79**	100%

(Rs. in Crore)
Source: Author's Estimations

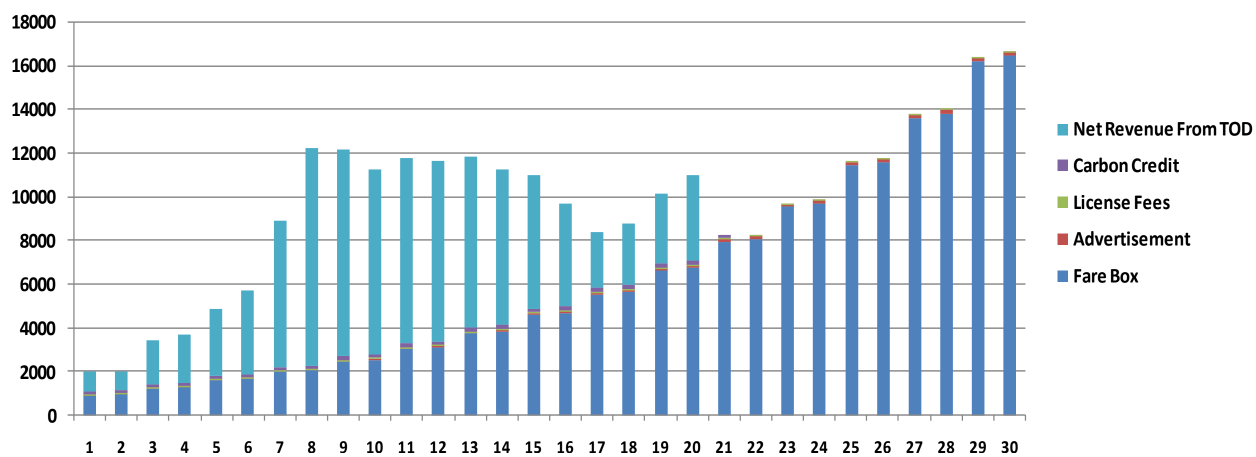
The estimated revenue for RRTS from various sources is summarized below;

Table 12-17: Summary of estimated revenue

Particular	2017	2021	2031	2041	2046
Fare Box	986	1630	4622	11462	16490
Advertisement	17	51	101	162	194
License Fees	6	11	20	29	34
Carbon Credit	109	142	180	0	0
Revenue From TOD	616	1066	9830	14021	0
Total	**1733**	**2899**	**14753**	**25673**	**16718**

Rs. in crore
Source: Author's Estimations

It can be seen that overall fare box collection contributes around 64% of the total revenue while TOD/property income is considered after deducting construction and administration cost for property development. It would be 33% of the total revenue. However the pattern of revenue stream in entire operation period is shown below:



Source: Author's Estimations

Figure 12-2: Pattern of revenue for RRTS

Revenue from property development is estimated to be the major source during middle years. Revenue from advertisement and licenses are envisaged to be trivial. The revenue from carbon credit is discussed in economic analysis in detail.

12.4. Estimations for Operations and Maintenance Cost

The Operation and Maintenance (O&M) cost for RRTS is segregated into six components like 1) Staff Salary 2) Repair and Maintenance expenses 3) Energy Expenses 4) Admin expense 5) Replacement cost. The O&M cost for RRTS is calculated mainly using cost of similar metro type rail systems.

12.4.1 Staff salary

Staff requirement is considered to be 35 persons per km. Thus total estimated staff required for RRTS would be thus 6300 persons. Following is the break up of the staff requirement and estimated salary.

Table 12-18: Break up of Staff and Salary

Designation	No. of persons required	Annual Salary CTC basis (Rs. Lakh)	Total salary (Rs lakh)
CEO	1	50	50
Vice Presidents	10	24	240
Dept. Heads	40	12	480
Middle level	320	10	3200
Technician/Supervisory Level	1300	5	6500
Others	4629	2.5	11573
Total	**6300**		**22043**

Source: Author's Estimations

The above salary is at 2011 prices which is escalated over 6 years to be the salary level of 2017. The growth rate in this expense is estimated to be 9% pa thereafter.

124.2 Repair and Maintenance Cost

Repair and Maintenance Expenses including cost of inventory for RRTS are expected to be around Rs. 0.9 crore pa. The cost is escalated at 6% pa.

12.4.3 Administrative Expenses

Administrative expenses are estimated as follows

Table 12-19: Administrative Expenses

Admin Expenses	
Insurance, legal, stationary, telephone, security, vehicle hire & maintenance, land license fee, loss on asset etc. (Rs lakh Cost per km)	25.00
Above Cost in Rs. Crore for RRTS	45.00

Travelling and conveyance etc pa. Rs crore	1.00
Misc pa (Rs crore)	5.00
Total	**51.00**

Source: Author's Estimations

12.4.4 Replacement Expenses

The replacement costs are calculated based on 10% replacement for project goods after 20 years of operations. The project goods which will be required replacement are as follows:

Table 12-20: Project goods to be considered for replacement

Project Goods	Cost (Rs. crore)
E & M Works	659
Permanent Way	1245
Traction and Power	846
Signalling and Telecom	1947
Utilities	227
Special noise & vibration reduction treatment	50
Total	**4974**

In addition to above rolling stock would be purchased and replaced periodically as follows:

Table 12-21: Purchase of rolling stock

	2021	2031	2041
Number of units (Cumulative)	318	396	477
Estimated Cost Per Unit (Rs Crore)	24	44	78
Purchase of Rolling stock (Rs. Crore)	1315	3402	6327

The cost for rolling stock at the beginning of operations is already included in the project cost. Purchase Cost for the future years are obtained by escalating existing prices.

12.4.5 Energy Expenses

Consumption of Electricity for traction and buildings is taken 0.30 crore unit/km/pa. The cost on account of power consumption would rise owning to cumulative impact of rise in consumption and rise in price of electricity. The overall escalation has been taken at 6% pa in energy expenses.

Table 12-22: Energy Expenses

Energy Expenses	
Total consumption (crore units) for RRTS	54
Price per unit (Rs)	4
Total expenses (Rs crore)	215

Following is the summary of estimated O&M expenses over the next 30 years.

Table 12-23: Summary of O&M expenses

Particular	2017	2021	2031	2036	2041
Staff Salaries	220	311	737	1133	1744
Repair & Maintenance Exp	162	205	366	490	656
Energy Expenses	215	271	486	651	871
Admin Expenses	51	64	115	154	206
Replacement in Equipment /Addition of Rolling Stock	0	1315	3402	1595	6327
Total	648	2167	5106	4024	9804

Source: Author's Estimations

As can been seen in the above table that staff salary and energy expenses are the significant contributors to the total O&M cost. The replacement in equipment and addition to rolling stock is taken only in certain years, which happen to be the years mentioned above.

12.4.6 Other Assumptions

The assumptions related to taxation, depreciation and amortization prescribed as per Company's Act 1956 and Income Tax Act, 1961 are as follows;

Table 12-24: Depreciation and Tax related Assumptions

Depreciable components	Dep. Rates As per Income Tax Act	Dep. Rates As per Companies Act
E & M Works	60%	7.07%
Traction and Power		
Signaling and Telecom		
Rolling Stock (BG)		
Utilities		
Special noise & vibration reduction treatment equipments		
Alignment and Formation	10%	1.63%
Important Bridges		
Station Buildings		
Depot		
Permanent Way		
CISF Barracks		
Amortization		
General Charges (Years)	5	
Income Tax Input		
Number of years for which 80IA benefit is available	10	
80 IA block of years	20	
Exemption Allowed u/s 80IA	100%	
MAT tax rate	19.35%	
Corporate Tax Rate	33.99%	
Cut off rate of Payable tax of the Book profit to introduce MAT	18.00%	

The corporate tax calculated in the financial model comprises of effects of Minimum Alternative Tax (MAT) as well as benefit available under IT Act. As per Income tax Act, u/s 80 IA, 100% income tax payable is exempted to infrastructure projects for a continuous period of 10 years during a block of 20 years. However during the exemption period, MAT is payable.

Based on the above estimations and inputs, a detailed financial model has been created to assess operational sustainability of RRTS and financial returns from the project. Operational Viability is discussed next.

12.5. Operational Viability

Operational Viability for the RRTS is assessed further. The projected Profit and Loss Account of the RRTS is as follows:

Table 12-25: Projected P&L account

Particular	2017	2021	2031	2041	2046
	Rs. Crore				
Revenue					
Fare Box	986	1630	4622	11462	16490
Advertisement	17	51	101	162	194
License Fees	6	11	20	29	34
Carbon Credit	109	142	180	0	0
Net Revenue From TOD	924	3051	6117	0	0
Total	**2041**	**4884**	**11041**	**11653**	**16718**
O&M Cost					
Staff Salaries	220	311	737	1744	2683
Operations (Traction Expenses)	72	91	163	292	390
Energy Expenses	215	271	486	871	1165
Repair & Maintenance exp	90	114	203	364	488
Admin Expenses	51	64	115	206	276
Replacement in Equipment (10% of Project Cost)	0	1315	3402	6327	0
Total	**648**	**2167**	**5106**	**9804**	**5002***
Operating Revenue (EBIDTA)	**1393**	**2717**	**5934**	**1849**	**11715**
Operating Revenue/Total Revenue	***68%***	***56%***	***54%***	***16%***	***70%***
Interest	412	412	288	151	82
Depreciation (As per Cos Act)	900	900	368	279	279
Amortization	131	131	0	0	0
Profit Before Tax	-50	1275	5278	1419	11354
Tax	0	0	1786	531	3927
Profit After Tax	-50	1275	3491	889	7428

**Lower since there are no replacement costs in that year*

It can be seen that the fare income is able to cover the operating expenses and the project is operationally viable even based on fare income alone. However, fare revenues are not sufficient to allow recovery of investments in the project. For this purpose, property development is required.

Overall, the operating surplus is estimated to remain around more than 65% over the projection period. It is mainly due to Fare box revenues being supported handsomely by property development income. The fare revenue would grows at 10% for 30 years while property revenues increase at 8% pa for 20 years compares to 7% pa increase on an average in O&M expenses over 30 years. The operating ratio is only decreasing during periodic replacement.

Further, the property development income is expected to be gained either through development by the RRTS Special Purpose Vehicle (SPV) itself or through involvement of developers. Developer involvement through PPP models for development of property can be station wise, or through packages or number of stations. The developer would be allowed to carry out commercial development on the basis of payment of upfront annual premium to the RRTS SPV. It is expected that the upfront premium payable by the developers in this case would be equal to the property income estimated here. The profits for the developer would come from increase in efficiency through lower costs of development, faster absorption and better lease rates.

12.6. Means of finance

Following is proposed means of finance for the project in the base case. The contribution to equity is as per the MOU signed between the stakeholder Governments. The role of Govt. of Uttar Pradesh is not relevant in this case as the project does not pass through the State. This contribution of Uttar Pradesh has been replaced by contribution from Govt. of India under some other funding scheme.

Table 12-26: Means of finance – Base Case

Means of Finance	Contribution	Rs. Crore
Equity Contribution	**30%**	**9290**
Contribution from GOI (MOUD, MOR and NCPRB)	*63%*	*5806*
GNCT –Delhi	*12.50%*	*1161*
Govt. of Haryana	*12.50%*	*1161*
Govt. of Rajasthan	*12.50%*	*1161*
Contribution from Govt. of India in place of contribution from Govt. of Uttar Pradesh	*12.50%*	*1161*
Senior Debt	**70%**	**21676**
Term loan from Multi Laterals		
Interest Rates	1.90%	
Repayment Tenure (years)	30	
Grace Period (years)	5	
Effective Period (Years)	35	
Subordinated Debt (Interest Free Loan)		
Central Government		**2612**
Repayment Tenure (years)	10	
Total		**33578**

Source: Author's estimations

Debt is assumed to be available from multilaterals like JICA at a concessional rate of interest. The proposed RRTS seems capable of sustaining this level of debt. The minimum DSCR works out to be 2.97. The average DSCR is 10.5.

Alternative Scenarios for means of finance are discussed after presenting the financial returns in the above base case.

12.7. Financial Returns

The calculation of financial returns for RRTS based on projected cash flow for RRTS is as follows;

Table 12-27: Projected cash flow in the Base Case

Particular	2012	2013	2014	2015	2016	2017	2021	2031	2041	2046
Outflows										
Project Investments	2920	6215	9919	10592	3931		0	0	0	
O&M Costs						648	2167	5106	9804	5002
Taxes						0	0	1786	531	3927
Total Outflows (A)	**2920**	**6215**	**9919**	**10592**	**3931**	**648**	**2167**	**6893**	**10335**	**8929**
Inflows										
Revenue						2041	4884	11041	11653	16718
Total Inflows (B)	0	0	0	0	0	2041	4884	11041	11653	16718
Net Cashflow (A-B)	**-2920**	**-6215**	**-9919**	**-10592**	**-3931**	**1393**	**2717**	**4148**	**1318**	**7789**
Project IRR	**12.01%**									

Source: Author's analysis

The Weighted Average Cost of Capital (WACC)3 of the project is around 7%. Thus the project is financially viable. The high proportion of low cost debt makes the project financially viable.

12.8. Alternative Scenarios for Means of Finance:

We have observed Means of Financing as per the Base Case earlier. However alternative scenarios for financing are required to be assessed given the large funding need. These are envisaged in terms of the following two alternate scenarios.

1. The Debt Equity ratio is retained at 70:30. All other assumptions too remain the same. However the cost of debt is raised to 6% as is available from some other multilaterals like the World Bank. It is found that the project can sustain this level of debt with a minimum DSCR of 1.2. However this level of debt is strained if the income from TOD / Property development is reduced by 30% (DSCR of 1) and the Project IRR is reduced to 9.71%.

2. The cost of debt funding is raised to commercial rate of 12% pa. The grace period is removed. Repayment period is reduced to 15 years from the present 30 years. All other assumptions remain the same. It is found that in this case, debt of 70% of

[3] ***WACC = (Debt (70%) * Cost of Debt (1.9%) + (Equity (30%) * Cost of Equity (20%)***

Cost of equity is considered based on dividend paid by Listed companies over last few years.

Project cost is not sustainable. (The minimum DSCR is reduced to 0.42). In order to make debt sustainable, debt levels have to be reduced to 25% of Project cost (ie Debt Equity ratio has to be made 25:75). Also the Project IRR is at unacceptable level of 11.7%. Even if VGF from the Government of India at 20% of the hard project cost is introduced, the PIRR only rises marginally at 13.67% which is less than the acceptable level of 18-20%. Thus the project is not viable on purely commercial basis as a whole.

12.9. Sensitivity Analysis

The section would assess sensitivity of the project returns and debt service capacity of the project to the changes in key variables. Following table shows effect on returns with change in Project cost, O&M cost and Fare revenue.

Table 12-28: Sensitivity analysis 1

Sr. No.	Particular	% change ±	PIRR		Min DSCR	
			With Increase	With Decrease	With Increase	With Decrease
	Basic Changes					
1	Project Cost	10.0%	11.14%	13.00%	2.70	3.30
2	O&M Cost	10.0%	11.74%	12.27%	2.97	2.97
3	Fare Revenue	10.0%	11.57%	12.26%	2.81	3.12
	Combinations					
4	Decrease in Project cost and Increase in Fare Revenue	10.0%	13.24%		3.47	
5	Decrease in O&M cost and Increase in Fare Revenue	10.0%	12.51%		3.12	
6	Decrease in Project cost and O&M cost and Increase in Fare Revenue	10.0%	13.50%		3.47	
7	Increase in Project cost and Decrease in Fare Revenue	10.0%	10.72%		2.56	
8	Increase in O&M cost and Decrease in Fare Revenue	10.0%	11.30%		2.81	
9	Increase in Project cost and O&M cost and Decrease in Fare Revenue	10.0%	10.44%		2.56	
10	**Change in Traffic Scenario**					
	Optimistic	-	12.39%		3.19	
	Realistic	-	12.01%		2.97	
	Pessimistic	-	11.35%		2.74	

Source: Author's analysis

It can be seen that the IRR is relatively sensitive to change in project cost compared to other key variables. Overall, viability is maintained even under change in key variables.

Other Sensitivities

Sensitivity of project returns to other key variables under the realistic scenario is as follows;

Table 12-29: Sensitivity analysis 2

Variables	Change	Change in PIRR
Tax on project goods	Elimination of tax	12.77%
Carbon Credit	Elimination of Income from CC	11.78%
Energy expenses	Increase by 8% pa	11.89%
Pass holders	Share of pass holder's in total traffic to be increased to 90%	11.63%
Net Income from Property	Reduced by 20%	10.6%
Net Income from Property	Reduced by 40%	9.27%
Net Income from Property	Reduced by 60%	7.65%

Source: Author's analysis

It can be seen that revenue from property impacts the financial returns the most. Thus the project's ability to provide adequate return on capital invested becomes strained in case of poorer returns from property development.

Annexure 1 : Km wise fares

Slab based flat fare						Distance based fare											
KM	Fare (Rs.)	KM	Fare (Rs.)	KM	Fare (Rs.)	KM	Fare (Rs.)	KM	Fare (Rs.)	KM	Fare (Rs.)	KM	Fare (Rs.)	KM	Fare (Rs.)	KM	Fare (Rs.)
1	15	**11**	20	**21**	25	**31**	32	**41**	37	**51**	47	**61**	56	**71**	65	**81**	74
2	15	**12**	20	**22**	25	**32**	32	**42**	38	**52**	48	**62**	57	**72**	66	**82**	75
3	15	**13**	20	**23**	25	**33**	32	**43**	39	**53**	48	**63**	58	**73**	67	**83**	76
4	15	**14**	20	**24**	25	**34**	32	**44**	40	**54**	49	**64**	59	**74**	68	**84**	77
5	15	**15**	20	**25**	30	**35**	32	**45**	41	**55**	50	**65**	59	**75**	69	**85**	78
6	15	**16**	20	**26**	30	**36**	33	**46**	42	**56**	51	**66**	60	**76**	69	**86**	79
7	15	**17**	20	**27**	30	**37**	34	**47**	43	**57**	52	**67**	61	**77**	70	**87**	80
8	15	**18**	20	**28**	30	**38**	35	**48**	44	**58**	53	**68**	62	**78**	71	**88**	80
9	15	**19**	20	**29**	30	**39**	36	**49**	45	**59**	54	**69**	63	**79**	72	**89**	81
10	15	**20**	20	**30**	30	**40**	37	**50**	46	**60**	55	**70**	64	**80**	73	**90**	82
Distance based fare																	
KM	Fare (Rs.)	KM	Fare (Rs.)	KM	Fare (Rs.)	KM	Fare (Rs.)	KM	Fare (Rs.)	KM	Fare (Rs.)	KM	Fare (Rs.)	KM	Fare (Rs.)	KM	Fare (Rs.)
91	83	**101**	92	**111**	101	**121**	111	**131**	120	**141**	129	**151**	138	**161**	147	**171**	156

92	84	**102**	93	**112**	102	**122**	112	**132**	121	**142**	130	**152**	139	**162**	148	**172**	157
93	85	**103**	94	**113**	103	**123**	112	**133**	122	**143**	131	**153**	140	**163**	149	**173**	158
94	86	**104**	95	**114**	104	**124**	113	**134**	123	**144**	132	**154**	141	**164**	150	**174**	159
95	87	**105**	96	**115**	105	**125**	114	**135**	123	**145**	133	**155**	142	**165**	151	**175**	160
96	88	**106**	97	**116**	106	**126**	115	**136**	124	**146**	133	**156**	143	**166**	152	**176**	161
97	89	**107**	98	**117**	107	**127**	116	**137**	125	**147**	134	**157**	144	**167**	153	**177**	162
98	90	**108**	99	**118**	108	**128**	117	**138**	126	**148**	135	**158**	144	**168**	154	**178**	163
99	91	**109**	100	**119**	109	**129**	118	**139**	127	**149**	136	159	145	**169**	155	**179**	
100	91	**110**	101	**120**	110	**130**	119	**140**	128	**150**	137	**160**	146	**170**	155	**180**	

13. Economic Analysis

13.1. Introduction

The Economic analysis of RRTS project has been undertaken with an objective to evaluate the contribution of proposed RRTS project to social objectives and to the economy.

In order to assess economic viability, economic benefits and costs associated with the project have been identified to the extent possible. The "With Project" scenario is compared with the option of "Without project scenario" to determine the economic benefits. The benefits consist of quantifiable and non quantifiable benefits. These are presented in table 12-1.

Table 13-1: Summary of Quantifiable and Non Quantifiable Benefits.

Benefits	Quantifiable Benefits	Non Quantifiable Benefits
Fuel Savings	√	
Savings in capex of Vehicle	√	
Savings in Road Infrastructure Capex	√	
Savings in Road Infrastructure maintenance cost	√	
Savings due to pollution reduction	√	
Passenger Time Savings	√	
Savings in VoC	√	
Savings due to accidents reductions	√	
Econ. Impetus to micro region		√
Overall increased mobility		√
Better urban planning		√
Benefits to City Image		√
Better access to workplace due to TOD		√
Better Comfort Level to Passengers Traveling on RRTS		√
Indirect benefits of Reduce Pollution to Population leaving around project corridor		√

Source: Author Analysis.

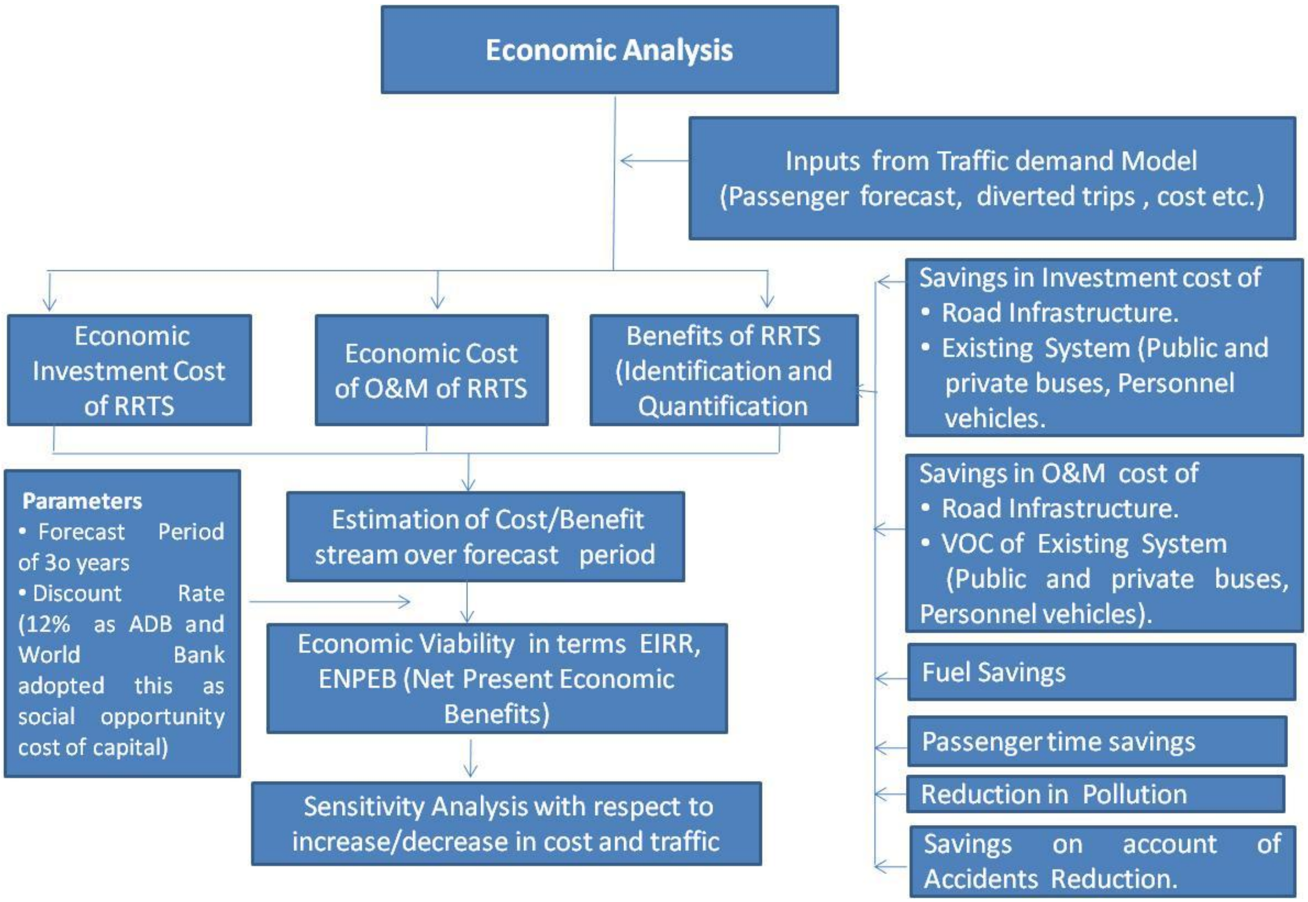
The total economic cost is subtracted from the total benefits to estimate the net benefit of the project. Discounted Cash Flow (DCF) technique has been used to determine the economic viability of the project. Detailed methodology and approach are described in subsequent sections. Final section discusses the economic viability of the project under the different sensitivity tests.

13.2. Approach and Methodology for Economic Analysis

The economic viability of the project has been carried out using the social cost benefit analysis approach and Discounted Cash Flow (DCF) technique. The financial project cost has been determined using the market prices. The economic project cost has been computed by applying appropriate conversion factor to the financial project cost. This has been done to remove distortion due to externalities and anomalies in market pricing system so as to arrive at true cost to economy. The detailed discussion pertaining to economic project cost is specified in economic cost section.

The project benefits have been computed through comparison of costs arising out of “with project” and “without project” scenario. For instance, in without project scenario, the economic costs incurred by the economy in carrying the diverted traffic to proposed RRTS project by the alternative mode of transport viz., road, rail has been computed. Therefore, the economic benefits would arise due to savings in cost that would accrue to the economy by moving the project traffic over the alternate mode of transport. In addition, other social benefits that would accrue to the economy due to savings of direct/indirect costs namely, fuel savings, environmental pollution, accident reduction, maintenance cost, passenger time savings etc . These have been computed using the “with project” and “without project” scenario. These savings in social costs have also been considered to the extent that they are quantifiable. These social benefits have been computed based on economic prices instead of market prices. Shadow prices have been used to arrive at the economic costs/benefits. To arrive at the shadow prices, appropriate conversion factors (for converting market prices to economic cost) have been applied.

The pictorial representation of methodology of Economic analysis is specified in Figure 13-1.



Source: Author Analysis.

Figure 13-1: Methodology for Economic Analysis

The annual stream of economic costs and benefits have been computed for analysis period of 30 years. Economic viability has been undertaken using the Discounted Cash Flow (DCF) technique to obtain the economic internal rate of return (EIRR %) and economic net present value (ENPV) for the proposed project. This is followed by a 'sensitivity analysis' by increasing or decreasing the critical factors affecting the cost and benefit streams of the proposed project, in order to ascertain their effect on the economic feasibility indicators i.e. ENPV, EIRR.

13.3. Estimation of Economic Project Cost of RRTS

The Economic project cost (i.e capital cost) of the RRTS is calculated from the financial project cost on the following basis.

- Tax components are excluded from the financial project cost as it represents transfer payments.
- Interest during Construction (IDC) has been excluded from the financial cost.
- On capital cost sides subsidies and market distortion including foreign exchange distortions are very difficult to evaluate. Therefore, the practice is to apply an overall conversion factor (CF) to cost figures to eliminate all possible distortions including foreign exchange distortions if applicable. ADB projects in the past have used in India a conversion factor (CF) equal to 0.90. Hence to eliminate all possible distortion owing to subsidies, wages of labourers and foreign exchange distortion, conversion factor equal to 0.9 have been used to arrive at Economic project cost.

The Economic project cost for the RRTS project is specified in table 13-2.

Table 13-2: Economic Cost of Project

Particular	Amount (Rs crore)
Project Cost including land cost (A)	**23765**
General Charges including Design Charges @ 3% of A : (B)*	**713**
Physical Contingencies @ 3% of A : (C)	**713**
Total cost (A + B + C) (Excluding IDC and Taxes) : **(D)**	**25191**
Economic Capital cost @ 0.9 of (D) above	**22672**

Source: Author Analysis

**Design charges include land layout design charges*

The development of RRTS project is proposed in five years. The proposed phasing of construction is explained in table 13-3.

Table 13-3: Phasing of Economic cost of Project

Year	Phasing	Economic Cost of Project (Rs crore)
2012	10%	2267
2013	20%	4534
2014	30%	6801
2015	30%	6801
2016	10%	2267
Total	**100%**	**22672**

Source: Author Analysis

As specified in above table that total economic cost of the project is arrived at Rs 22672 crore at completion. Total net present value of Economic cost of project has been arrived at Rs 16089 crore using the discount rate of 12%.

Estimation of Economic cost of Operation and Maintenance

Operation and maintenance costs under "with the project" situation are derived from financial O&M estimates. As per the prevailing practice, only real prices have been considered in computation of economic O&M estimates. The conversion factor equal to 0.9 is applied to arrive at economic O&M estimates. This is owing to adjust the market prices for transfer payment like taxes, subsidies etc. for operation, repair& maintenance, material requirement and staff salary. The O&M Cost also includes replacement cost. Detailed discussion on financial O&M cost is specified in Financial analysis chapter. Economic cost of Operation and Maintenance of RRTS project is summarized in table 13-4.

Table 13-4: Economic Cost of Operation & Maintenance

Particular	2017	2018	2019	2020	2021	2031	2036	2041
O&M Cost	533	533	533	533	1194	1487	1249	1524

(Amount in Rs.Crore)
Source: Author Analysis

Total net present value of Economic cost of O&M has been arrived at Rs 2822 crore using the discount rate of 12%.

13.4. Economic Benefits of RRTS

As discussed, in the Approach and Methodology section, proposed project will accrue tangible and non tangible benefits due to reduction in traffic to existing system. It also contributes to diversion of passenger traffic from alternate mode i.e Road and Rail to RRTS system. As a result there will be reduction in number of vehicles carrying passengers with introduction of RRTS and hence it also reduces congestion. This will also lead to savings in capex of transport system, i.e roads , rails, vehicles etc . In addition, other social benefits that would accrue to the economy due to savings of direct/indirect costs namely, environmental pollution, accident reduction, maintenance cost, passenger time savings, vehicle operating cost etc. Following table elaborates the quantifiable/non quantifiable benefit stream that would be accruing to economy with introduction of RRTS.

Table 13-5: Economic and Social Benefits arising from RRTS

S. No.	Benefit	Direct Benefit due to RRTS	In direct benefits due to decongestion on other modes/routes owing to RRTS
1	**Lower Capex in Vehicle i.e Bus, Car, Auto , Two wheelers ,Rail etc.**	RRTS would significantly contribute in diversion of Traffic from existing mode of transport. This will lead to savings in followings. • Capex of vehicles carrying the diverted trips. • Capex of alternate mode of transport i.e Road that would be required to cater to increased traffic, in case RRTS is not introduced.	
2	**Lower capex of Existing mode of Transport i.e Road etc.**		
3	**Reduced Road Stress**	Reduced need for road maintenance due to reduced traffic on account of diverted trips on RRTS.	
4	**Lower Vehicle Operating Cost**	Due to absence vehicles of diverted pax	Due to smoother operations of existing vehicles.

S. No.	Benefit	Direct Benefit due to RRTS	In direct benefits due to decongestion on other modes/routes owing to RRTS
5	**Fuel Saving**	Fuel saved on vehicles of diverted pax.	Fuel saved by plying vehicles due to smoother operations on decongested roads.
6	**Reduction in accidents**	Lower accidents due to absence of vehicles of diverted pax	Lower accidents from plying vehicles due to decongested roads / other modes
7	**Reduction in Pollution**	Absence of carbon emissions from vehicles of diverted pax.	Lower emissions on decongested roads.
8	**Passenger time saving**	• Higher speed of RRTS as compared to present transport system . • Reduction of waiting time for people diverted to RRTS from existing Bus and Rail owing to higher frequency and speed.	Due to faster speeds possible from lower congestions levels, though this may also encourage car owners who would otherwise use public transport to use cars.
9	**Better access to workplace due to TOD**	Shorter trip distances for workers employed on TOD stations, employment etc.	
10	**Econ. Impetus to micro region**	Better and faster accessibility due to RRTS may enhance labour pool and skill availability with multiplier benefits	Improved accessibility due to decongested roads/other modes may enhance labour pool and skill availability with multiplier benefits.
11	**Overall increased mobility**	Better quality of life to citizens, particularly to daily commuters, women, students, elderly and disabled.	Benefits resulting from reduced congestion captured, other benefits may not be captured.
12	**Better urban planning**	Would make possible integrating land use with transport, enabling better town planning and contributing to efficiency due to better allocative efficiency of capital.	
13	**Benefits to City Image**	Would improve city image attracting higher investments and businesses, could decrease	

S. No.	Benefit	Direct Benefit due to RRTS	In direct benefits due to decongestion on other modes/routes owing to RRTS
		outmigration and increase immigration.	
14	**Better Comfort Level to Passengers Traveling on RRTS**	Improved quality of services, ease, reduction in crowding owing to higher frequency and speed. These factors enhance Comfort Level to Passengers.	
15	**Indirect benefits of Reduce Pollution to Population leaving around project corridor**	Diversion of Traffic will also contribute to reduced congestion and pollution there of.	

Impact can be quantified using proxies and estimates when necessary

Impact difficult to quantified due to absence of universally accepted methods

Source: Author Analysis

Estimates of quantifiable benefits are explained in subsequent sections. While non quantifiable benefits have been drawn in to analysis by taking 10% of total quantifiable benefits as non quantifiable/Other benefits.

13.4.1 Transport Demand on RRTS

Existing Transport system on project corridor consist of Buses, Railway, shared auto rickshaw, cars and two wheelers. Traffic chapter provides details of the traffic demand estimates. The traffic demand estimates is shown in table 13-6.

Table 13-6: Traffic Demand on RRTS

Particular	2017	2021	2031	2041	2046
Total Peak hour Diverted Trips (Lakh)	0.74	0.91	1.26	1.51	1.68
Total Trips on RRTS (Lakh/ day)	7.37	9.12	12.55	15.11	16.27
Average Trip Length (km)	27.1	25.96	27.69	28.78	29.3

Source: Traffic Estimates and OD Analysis

Occupancy factors of different category of vehicles have been arrived based on actual traffic survey. These occupancy figures have been used to arrive at the numbers of diverted vehicles.

Table 13-7: Occupancy factors of different category of vehicles

Type of Vehicle	Occupation Factor/ Capacity Utilization
Two Wheelers	1.5
Car	2.25
Auto	5
Public Transport (BUS)	41.34
Rail	720[4]
Rolling stock (Engine+ coaches) per train	11

Source: Traffic Survey

Above occupancy factors have been applied to total daily diverted trips to arrive at the daily diverted vehicles.

Table 13-8: Daily Diverted Vehicles

Particular	2017	2021	2031	2041	2046
Two Wheelers	113946	156217	262151	296171	305824
Car	59306	87940	145055	155000	155656
Auto	16736	23447	25691	46607	60983
Public Transport (BUS)	7967	8304	9314	11108	11785
Rail	27	27	31	35	37
Total	**197981**	**275935**	**442243**	**508922**	**534285**

Source: Author Analysis

Based on Origin Destination analysis, average trip distance has been found out which has been specified in Table 12-6. Annual vehicle run has been derived based on product of annual numbers of vehicle plying on the RRTS corridor and average trip length.

[4] Majority of long route trains are plying on this route and each train has 10 coaches with carrying capacity of 72 persons per coach.

13.4.2 Savings in Capital Cost of Vehicles

As specified above, with introduction of RRTS, there would be a reduction of vehicles such as Two wheelers, Cars, Auto, Buses, Rail etc on proposed corridor. As indicated in table above , there would be a daily reduction of 197981 vehicles alone in 2017 . This reduction of vehicles corresponds to savings of capital expenditure. Further there would be a reduction of replacement cost of vehicles as each vehicle category has limited operational life. The operational life of Two wheelers, Car, Auto, Bus, Rail (Rolling stocks) have been considered 5 years, 12 years, 7 years, 10 years and 20 years respectively. This is based on prevailing industry practice.

In spite of efficient public transport system, there is a desire for owning a car and two wheelers among the people for weekends and for travelling outside the city. Thus it is assumed that only one third of the diverted passengers (people diverted to RRTS and who would use the RRTS for commuting to work) would not be purchasing car and two wheelers.

Following estimates have been undertaken to arrive at savings in capex of different category of vehicles.

Table 13-9: Economic Price of Different Type of Vehicles

Particular	Financial Price of Vehicle at 2011 prices (Rs.)	Economic Price of Vehicle @ 0.9 of financial price at 2011 prices (Rs.)
Two Wheelers	50000	45000
Car	400000	360000
Auto	180000	162000
Public Transport (BUS)	2400000	2160000
Rail (Rolling stocks)	50000000	45000000

Source: Various sources and respective website of vehicle manufactures, Author Analysis.

Above mentioned economic prices of different vehicles have been used to arrive at savings in capex of vehicles which would have been diverted in "With RRTS Project" scenario. The savings with respect to diverted vehicles would be Rs 6479 crore in 2017 for the project. Year wise savings in capex of vehicles are specified in Annexure-1.

Total savings in economic cost of the vehicle during the 30 years operational years of RRTS would be Rs 5080 crore in present value terms. The discount rate of 12% is used to arrive at present value.

13.4.3 Savings in Road Infrastructure Cost

The RRTS system would bring savings in investment in Road infrastructure. This is owing to shifting of passengers to RRTS system and reduction in vehicle in existing road infrastructure thereof. Owing to unavailability of information pertaining to existing capacity of road, it is assumed that diverted traffic would be accommodated in separate road corridor along the RRTS project corridor.

Indian Road Congress's norms for the PCU factors for various vehicle types have been used to arrive at peak hour PCUs of diverted traffic.

Peak hour Road capacity norms for level of service C, stipulated by Indian Road Congress (IRC) have been used to arrive at road infrastructure requirements. Based on this, it is worked out that total of three eight lane road and one four lane road would be required during operational years to accommodate the diverted traffic in "Without RRTS Project" scenario. Thus RRTS project would contribute in savings in road infrastructure investment in three eight lane roads and one four lane road.

Following road infrastructure cost norms have been used to arrive at Road infrastructure investment requirement.

Table 13-10: Norms used for Economic cost of Road Infrastructure

Capacity of Road	Financial Cost per KM (Rs crore) in 2011	Economic Cost per KM (Rs crore) in 2011 @0.9 of financial cost
4- lane	9.6	8.6
6-lane	13	11.7
8- lane	17.6	15.8

Source: Planning Commission constituted B K Chaturvedi committee report for road infrastructure cost estimates[5].

[5] B K Chaturvedi committee estimated road infrastructure cost of 4- lane and 6- lane road as Rs 9.6 crore per km and Rs 13 crore per km in 2010-11 respectively.

Total savings in economic cost of the Road infrastructure during the 30 years of operational period would be Rs 3437 crore in present value terms. The discount rate of 12% is used to arrive at present value.

13.4.4 Savings in Road Infrastructure Maintenance Cost

As specified above, RRTS project would contribute in savings in road infrastructure investment in three eight lane roads and one four lane road. This will also lead to savings in road maintenance cost of these corridors which would have been occurred in "Without Project" scenario.

Prevailing industry norms for routine maintenance and periodic maintenance of Road infrastructure have been adopted in order to arrive at economic maintenance cost of Road infrastructure[6].

Total savings in economic Road infrastructure maintenance cost during the 30 years of operational period would be Rs 692 crore in present value terms.

13.4.5 Savings in Fuel Consumption

As a result of diversion of vehicular traffic to RRTS System, there would be a considerable savings in fuel consumptions. There would be an inter- fuel substitution of

Savings in Fuel Consumption = (Annual Run of each Diverted Vehicle (i.e Vehicle Km)/ Fuel consumption Norms of different category of Vehicle i.e mileage) X Respective Fuel Prices.

Using the above formula it is estimated that total cumulative savings in Petrol, Diesel and CNG are 30999 lakh lit. , 13692 lakh lit., and 11399 lakh kg respectively during the thirty years of operational period. Fuel consumption norms used in analysis are stipulated in table 13-11.

[6] Annual Routine maintenance is adopted 1.5% of economic cost of road project. Periodic maintenance at 5% of economic project cost at regular interval of 5 years.

Table 13-11: Fuel Consumption Norms

Mode	Fuel Consumption Norms (Mileage)
Two wheelers (km/lit) (Petrol)	35
Car (km/lit) (Petrol)	13
Car (km/lit) (Diesel)	16.9
CNG Bus (km/KG)	2.94
Diesel (Km /Lit) for Bus	2.94
Auto Petrol (Km/Lit)	20
Auto CNG (Km/kG)	31.2
Consumption of Diesel per train km (Lit. per train km)	3.50

Source: Various sources, DTC, Industry estimates

It is also assumed that fuel of Auto and Bus shall be substituted by CNG from 2023 onwards. Prevailing fuel prices in Delhi as on 20th September, 2011 has been used to compute the savings in fuel consumptions.

Table 13-12: Fuel Prices

Type of Fuel	Price of Fuel
Petrol (Rs/lit)	66.84
Diesel (Rs/Lit)	46.2
CNG (Rs/KG)[7]	33.4
Power (Price per unit) (Rs)	4

Source: IOCL, BPCL and Various sources. Note: Prices as on 20th September, 2011

Based on above, corresponding cumulative fuel savings would be Rs 3691 crore in net present value terms during the 30 years of operational period. Detailed year wise savings in fuel is presented in Annexure-1.

13.4.6 Savings due to Accident Reduction

The reduction in traffic volumes on road owing to modal transfer to RRTS System is expected to reduce the accidents on project corridor. Further reduction in accidents will also lead to savings from damage to vehicle and savings towards medical and insurance expense to personnel involved in the accidents. This also leads to reduction of productivity to the economy by the persons involved in the accident. Further it is to be

[7] *Source: Average price In NCR Region as on 18 august, 2011.*

noted that highest safety standards have been considered for RRTS project so as to have minimal chance of accidents in RRTS system.

Owing to unavailability of past records of the accidents for vehicles plying in project corridor, The relationship exist between the number of vehicle playing and number of persons killed and injured in road accidents as specified in Road User Cost Study (CRRI, 1982) which is later updated by Dr. L.R. Kadiyali in association with Loss Prevention Association of India, have been considered[8] to measure the accident cost to the economy. This relationship is specified below.

1. **No of person Killed in Road Accidents:** Y1 = 49.43 *X + 750.42, Where: X= No of Vehicles affected in Lakh, Y1= number of persons killed in road accidents in a particular year, R square= 0.89.
2. **No of person injured in Road Accidents:** Y2 = 257.04 * X + 3181.41, Where: X= No of Vehicles affected in Lakh, Y2= number of persons injured in road accidents in a particular year, R square= 0.90.
3. **Damage of Vehicles :** Y = 143.63 * X + 3345, Where : X= No of Vehicles on the road , Y= damage to the vehicle in a particular year, R square= 0.90

Further to above past road accidents records stipulated by MORTH[9] have been assessed which displayed declining trends in road accidents and persons killed. The outcome of accidents estimated using the formula above is much higher than the accidents trends displayed by MORTH records. **Thus a very conservative approach has been undertaken by using the MORTH level of accidents estimates for future accidents in the "Without RRTS Project" scenario.**

Further to above, the Road User Cost Study also estimated cost of accidents which included components like gross loss of future output due to death/major injury, medical treatment expenses, legal expenses, and administrative expenses on police, insurance companies and the intangible psychosomatic cost of pain. The value of accidents and damaged to vehicle is presented in table 13-13.

[8] *Source: Planning Commission constituted study "Social Cost Benefit Analysis of Delhi Metro" by Institute of Economic Growth by RITES*
[9] Ministry of Road Transport & Highway

Table 13-13: Economic Cost of Accident

Particular	Economic Cost (at 2011-12 Prices)
Cost of fatal accident (person killed) (Rs at 2011-12 prices)	437342
Cost of fatal accident (person Injured) (Rs at 2011-12 prices)	64256
Cost of damage to Two wheelers	2286
Cost of damage to Car	9763
Cost of damage to Bus	32818
Cost of damage to Auto	3900

Source: Planning Commission constituted study "Social Cost Benefit Analysis of Delhi Metro" by Institute of Economic Growth by RITES

Based on above, the reduction in accidents for different types of vehicles is estimated. The estimates of cost of damage to cars, buses and two-wheelers in road accidents, as reported in the above table are used to estimate the total savings in compensation paid due to damage caused vehicles. Thus total savings of Rs 2952 crore is estimated due to accident reduction in present value terms during the thirty years of operational period. Year wise details are presented in Annexure-1.

13.4.6 Savings due to Pollution Reduction

Factors such as fewer vehicles due to diversion to efficient RRTS System and decongesting existing road and rail network, would lead to reduction in green house gas emission in the region.

Unlike the existing transport system, which runs on a combination of petrol, diesel and CNG, the proposed RRTS Project will be operated entirely through electric system, thereby further enhancing the GHG emission reduction potential of the project.

Considering the above potential, United Nations Framework Convention for Climate Change (UNFCCC) approved methodology i.e "ACMOO16" for rail based MRTS have been used to estimate the possible carbon emission reduction. This methodology has been stipulated by UNFCCC under the possible financing through Clean Development Mechanism (CDM).

Based on above Methodology, Carbon finance i.e Monetization of emission reduction is calculated as follows.

Carbon Finance = Emission Reduction from RRTS Project x Price of per tone of CO2.
Emission Reduction from Project: Baseline Emission (In without project, BAU) **-** Project Emission (Direct Project Emission + Indirect Project Emission).

The price of per tonne of CO2 is considered as Rs 800, which was carbon trading price in spot market in European Energy Exchange as on 12th August, 2011.

In order to estimate baseline emission, emission per kilometer run of each vehicle category has been estimated. Default vehicle technology improvement factor of 0.99 as stipulated under the UNFCCC methodology has been used to arrive at year wise emission factor of each vehicle category. Following emission parameters along with vehicle technology parameters has been used to estimate emission factor for each vehicle category.

Table 13-14: Emission Parameters

Particular	Value	Unit
Net calorific value gasoline/Petrol	43.9	MJ/kg
Net calorific value diesel	42.7	MJ/kg
Net calorific value CNG	35.6	MJ/m3
Specific weight gasoline	0.759	kg/l
Specific weight diesel	0.83	kg/l
Specific weight CNG	0.717	kg/m3
CO2 emission factor gasoline	67.5	gCO2/MJ
CO2 emission factor diesel	72.6	gCO2/MJ
CO2 emission factor CNG	54.3	gCO2/MJ
CH4 emission factor of CNG buses	162	gCO2/km
CH4 emission factor of CNG light vehicles	9.9	gCO2/km

Source: BPCL and IPCC

Based on above inputs, emission parameters for each vehicle category and baseline emission in without project scenario has been estimated.

In order to estimate the saving in carbon emission, project emission (Emission due to RRTS Project) is estimated using the UNFCCC methodology. The methodology stipulated following formula for estimating the direct project emission.

$$PE_{y} = EC_{pj,j,y} \times EF_{el,j,y} \times (1 + TDL_{j,y})$$

Where,

$EC_{pj,j,y}$ = Quantity of electricity consumed by the project electricity consumption source j in year y (MWh/yr).

$EF_{el,j,y}$ = Emission factor for electricity generation for source j in year y (tCO_2/MWh).

$TDL_{j,y}$ = Average technical transmission and distribution losses for providing electricity to source j in year y

Following inputs have been plugged into above formula to estimate direct project emission.

Table 13-15: Emission Parameters for electricity grid

Particular	Value	Unit
Emission factor of Indian grid (EF el, j,y)*	0.81	tCO2/MWh
Average technical transmission and distribution losses for providing electricity (TDL j,y)**	3.91%	Percent

Source: * Emission factor of National Grid by Central Electricity Authority, ** Power Grid Corporation of India, 2010.

Based on above norms , reduction in total emission is estimated at 60 million tones CO2 during the operational period of 30 years.

Thus, pollution emission savings has been arrived at Rs 668 crore in net present value terms during the 30 years of operational period. Detailed year wise savings due to pollution reduction is presented in Annexure-1.

13.4.7 Passenger Time Savings

The RRTS system would be faster than alternate transport mode i.e road transport modes, existing rail etc. This will also lead to considerable saving in time of passenger travelling on RRTS System. The savings of travel time of passenger travelling by RRTS instead of alternate mode of transport is calculated as follows:

Passenger Time Savings = (Time spent by diverted Passenger on RRTS - Time spent by diverted passenger on alternate transport mode) X Value of Passenger time

Average speed of two wheeler, car, shared auto, Bus and Existing railway is estimates at 25 km/hr, 40 km/hr, 15 km/hr, 35 km/hr and 50 km/hr respectively in the without project scenario. Speed of proposed RRTS is estimated at 90 km/hr, thus bringing enormous time saving benefits. Any benefits due to increase in speeds due to decongestion taking place on the roads in the "With Project Scenario" has not been considered in the analysis as we expect only a marginal rise in speeds and hence only very limited time savings.

The estimates for economic value of passenger time are stipulated below.

Table 13-16 : Economic Value of Passenger Time[10]

Vehicle Category	Value of Time of Passenger (Rs per hour of Passenger) at 2011 prices
Two wheelers	100
Car	200
Auto	75
MRTS (Bus and Existing Railway)	75

Source: Author Estimates

With the implementation of the RRTS project, the total passenger time savings are estimated at Rs.10,139 crore during the operational years in present value terms. Detailed year wise passenger time savings due to RRTS Project is presented in Annexure-1.

13.4.8 Savings in Waiting Time

Further it is also estimated that RRTS would bring benefits in terms of reduction of waiting of approximately 10 minutes for people diverted from existing Bus and Rail. Though the benefit accruing is meager and valued at Rs 5.13 crore during the operation period.

[10] *Daily average Income of passengers travelling on different vehicle category have been divided by daily working hours to arrive at value of passenger time.*

13.4.9 Savings in Vehicle Operating Cost

The reduction in vehicle operating cost (VoC) of diverted vehicle is obtained as product of annual run of diverted vehicle and VoC/ vehicle km.

Table 13-17: Vehicle Operating Cost

Vehicle Category	Voc/Km in 2011 (Rs)
Two wheelers	0.5
Car	1.25
Auto	1
Bus	15

Source: Industry norms and Author estimates

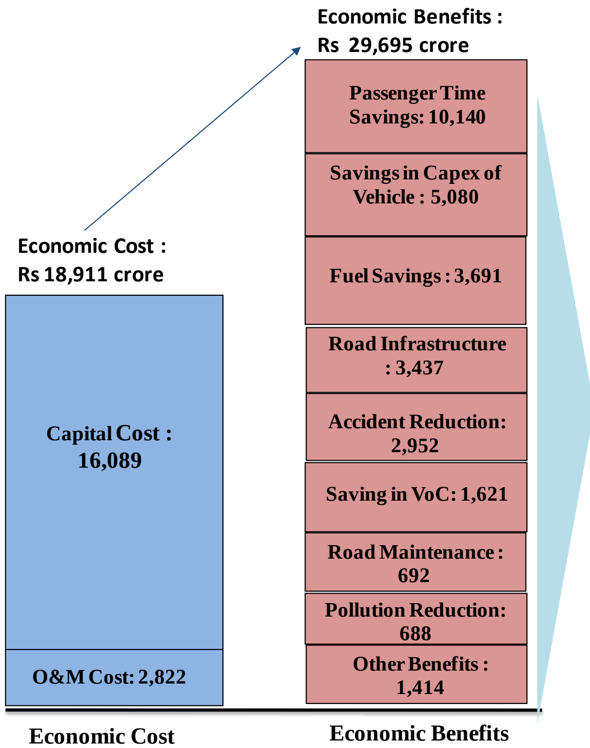
With the implementation of the RRTS project, the total savings in Vehicle Operating cost of diverted trips are estimated at Rs. 1621 crore during the operational years in present value terms. Year wise details are presented in Annexure-1.

13.5. Outcome on Economic Viability

The detailed discussion on outcome and sensitivity tests is specified below.

As discussed in section above, the cost and benefits streams for the thirty years period in economic prices have been estimated and presented in Annexure-1[11]. Further, the Discounted Cash Flow (DCF) technique has been used to obtain the economic internal rate of return (EIRR) and economic net present value (ENPV) for the RRTS Project. The result of the economic analysis is presented in Figure 13-2 below. The benefits are listed in the order of their magnitude, with the largest benefits accruing out of time savings of passengers (about one third).

[11] It is to be noted that the residual value of the RRTS project in last year has not been taken into account as benefit.



Particular	Outcome
Economic Internal Rate of Return @ 12% discount rate	18.57%
Economic net present value (ENPV) @ 12% discount rate (Rs crore)	10,784
Benefits to Cost ratio	1.57

Figure 13-2: Outcome of Economic Analysis

Source: Author Analysis, Amount (Rs crore) in present value terms. (Graph not to scale)

As discussed above, in realistic/base traffic demand scenario, economic viability analysis is 18.57% EIRR which is higher than social cost of capital i.e 12%.

Above economic appraisal is based on estimates of project cost and benefits which indicates that economic viability of the project to a large extent depends on realization of these estimated benefits. Circumstances and situations which negate, or limit these economic benefits may reduce the economic viability. Similarly, situations of uncaptured benefits, or those that accelerate or enhance the value of captured benefits may further improve the economic rate of return.

To understand the impact of increase/decrease of critical factors such as economic cost, traffic and benefits on economic viability of the project to a certain extent, sensitivities tests with respect to followings have been carried out.

a) Increase / decrease in Traffic with optimistic and pessimistic traffic scenario.

b) Increase in Economic Cost of the Project by 10%.

c) Decrease in benefits by 10%.

d) Combined scenario of increase in Economic Cost of the Project by 10% and decrease in Economic benefits by 10%.

The result is presented in Figure 13-3 below.

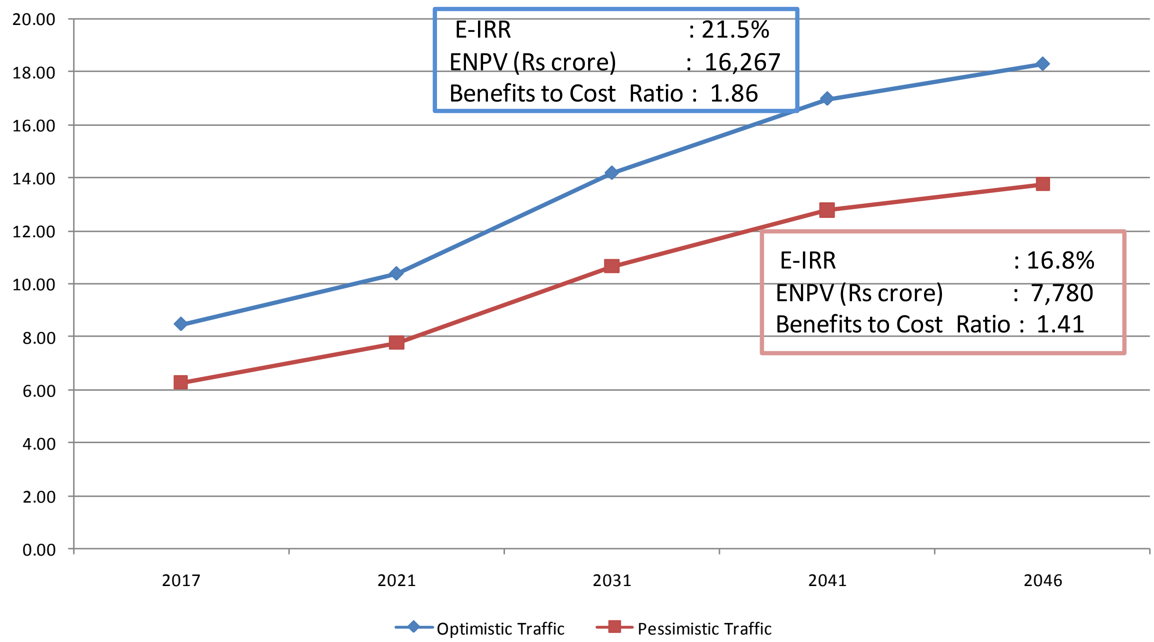


Figure 13-3: Economic Viability under Optimistic and Pessimistic Traffic

Source: Author Analysis, BC Ratio= Benefit to Cost Ratio

The outcome of the economic viability under above mentioned sensitivity tests are presented in table below.

Table 13-18 : Economic Viability of Project under Different Sensitivity tests

Particular	Economic Internal Rate of Return @ 12% discount rate	Economic net present value (ENPV) @ 12% discount rate (Rs crore)	Benefits to Cost ratio
Increase in Economic Cost of the Project by 10%.	17.17%	9,175	1.45
Decrease in benefits by 10%.	16.87%	7815	1.41
Combined scenario of increase in Economic Cost of the Project by 10% and decrease in Economic benefits by 10%.	15.57%	6206	1.30

Source: Author Analysis

It is seen from the above table that under the different sensitivity tests, EIRR is more than 15% which is higher than the social cost of capital i.e 12%.

13.6. Conclusion

Following conclusion can be drawn from the economic analysis of the project.

- Project provides 18.57% of E-IRR which is higher than the social opportunity cost of capital i.e 12% % normally used in the Asian context by ADB and World Bank. Thus on these counts, the returns are higher than the opportunity cost.
- Further it also provides 1.57 of benefits to cost ratio indicating 57% higher benefits would be accrued to the economy than the economic cost of the project if project is undertaken.
- Project provides E-IRR of 15.57% under the most pessimistic scenario of increase in economic Cost of the Project by 10% combined with a decrease in economic benefits by 10% which is also determined to be higher than social cost of capital.
- Thus project is determined to be economically viable.

Annexure 2: Economic Cost and Benefit Streams for the Project

Year	Economic Cost			Benefits											Net Benefits
	Capital Cost	O&M Cost	Total Cost	Fuel Savings	Savings in capex of Vehicle	Savings due to accidents reductions	Savings in Road Infrastructure Capex	Savings in Road Infrastructure maintenance cost	Savings due to pollution reduction	Passenger Time Savings	Savings in VoC	Savings due to Waiting time reduction	Other Benefits	Total Benefits	
2012	2267	0	2267	0	0	0	0	0	0	0	0	0.00	0	0	-2267
2013	4534	0	4534	0	0	0	0	0	0	0	0	0.00	0	0	-4534
2014	6801	0	6801	0	0	0	0	0	0	0	0	0.00	0	0	-6801
2015	6801	0	6801	0	0	0	0	0	0	0	0	0.00	0	0	-6801
2016	2267	0	2267	0	0	0	0	0	0	0	0	0.00	0	0	-2267
2017	0	533	533	554	6479	408	5686	85	109	1528	259	0.15	755	15864	15331
2018	0	533	533	591	165	443	0	85	117	1619	270	0.15	165	3456	2923
2019	0	533	533	631	167	481	0	85	125	1715	282	0.15	174	3662	3129
2020	0	533	533	673	169	522	0	85	134	1816	295	0.15	185	3879	3347
2021	0	1194	1194	718	171	566	0	370	143	1922	308	0.15	210	4408	3214
2022	0	533	533	755	317	594	0	85	152	2004	321	0.15	211	4440	3908
2023	0	533	533	733	164	622	0	85	156	2089	335	0.16	209	4394	3862
2024	0	533	533	772	438	652	0	85	149	2178	349	0.16	231	4855	4323
202	0	533	533	813	194	684	0	85	154	2271	363	0.16	228	4793	4260

Year	Economic Cost			Benefits											Net Benefits
	Capital Cost	O&M Cost	Total Cost	Fuel Savings	Savings in capex of Vehicle	Savings due to accidents reductions	Savings in Road Infrastructure Capex	Savings in Road Infrastructure maintenance cost	Savings due to pollution reduction	Passenger Time Savings	Savings in VoC	Savings due to Waiting time reduction	Other Benefits	Total Benefits	
5															
2026	0	533	533	857	199	717	2843.1	412	158	2368	378	0.16	397	8328	7795
2027	0	533	533	902	2088	751	0	128	163	2468	394	0.16	345	7238	6706
2028	0	533	533	949	238	786	0	128	167	2573	411	0.17	263	5516	4983
2029	0	533	533	999	918	823	0	128	172	2683	428	0.17	308	6459	5926
2030	0	533	533	1052	289	862	0	128	177	2797	445	0.17	287	6037	5504
2031	0	1487	1487	1106	568	902	0	554	181	2916	464	0.17	335	7026	5539
2032	0	533	533	1125	480	915	0	128	186	2989	473	0.17	315	6610	6078
2033	0	533	533	1143	337	928	0	128	183	3064	482	0.18	313	6578	6046
2034	0	533	533	1161	301	941	0	128	180	3142	491	0.18	317	6662	6129
2035	0	533	533	1180	309	954	0	128	177	3222	501	0.18	323	6793	6261
2036	0	1249	1249	1198	2009	967	0	554	173	3305	510	0.19	436	9153	7904
2037	0	533	533	1217	4079	981	0	128	169	3390	520	0.19	524	11008	10475
2038	0	533	533	1236	613	994	0	128	169	3478	530	0.19	357	7506	6973
2039	0	533	533	1254	387	1008	0	128	170	3569	540	0.20	353	7409	6876

Year	Economic Cost			Benefits												Net Benefits
	Capital Cost	O&M Cost	Total Cost	Fuel Savings	Savings in capex of Vehicle	Savings due to accidents reductions	Savings in Road Infrastructure Capex	Savings in Road Infrastructure maintenance cost	Savings due to pollution reduction	Passenger Time Savings	Savings in VoC	Savings due to Waiting time reduction	Other Benefits	Total Benefits	
2040	0	533	533	1273	388	1021	0	128	170	3662	550	0.20	360	7553	7020
2041	0	1524	1524	1292	1106	1035	0	554	171	3759	560	0.20	424	8901	7377
2042	0	533	533	1306	653	1045	0	128	171	3845	568	0.21	386	8103	7570
2043	0	533	533	1320	484	1055	0	128	170	3933	576	0.21	383	8051	7519
2044	0	533	533	1334	426	1065	1555.2	151	170	4024	585	0.21	466	9776	9243
2045	0	533	533	1348	707	1075	0	151	169	4118	593	0.21	408	8569	8036
2046	0	533	533	1361	2166	1085	0	578	168	4214	602	0.22	509	10683	10150

Amount in Rs Crore

14. Way Forward

14.1. Next Steps

After submission of this Feasibility Report, a Stakeholders' Workshop will be organised for about 100 participants, in consultation with the Client. The issues required to be discussed in this workshop will be identified beforehand, and the concerns of the stakeholders during the workshop will be compiled. A report summarising and addressing the stakeholders' issues will be prepared and submitted to the client within two months of the approval of the Feasibility Report.

14.2. Assistance required from various Authorities

Field work of the Topographic survey of the identified alignment has been completed. The alignment is being marked on the Topo sheets and the Revenue maps. Once this work is completed, the land for the line and land parcels for stations, parking and Transit Oriented Development (TOD) will be identified. Our endeavour is to complete this work before holding the Stakeholders workshop, so that the land and other issues may be put up before them. On a preliminary assessment, the major issues are concerning availability of land and ROW for the RRTS, its Depots, Sub-stations, land parcels for TOD, identification of Utilities which would need to be diverted, and R & R issues. The Stakeholders would include three State Governments, MORTH (NHAI), AAI, DLF, HSIDC, RIICO, Ministry of Railways, DMRC, DDA, MCD, NDMC, DTC, Electricity Authorities in the three States, and Land & Development Authority.

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AFTC	Audio Frequency Track Circuits
ARSD College	Atma Ram Sanatan Dharm College, Delhi
ATO	Automatic Train Operation
ATP	Automatic Train Protection
ATS	Automatic Train Supervision
BTK	Bhiwadi- Tapookara- Khushkhera Complex
CAR	Corridor Alignment Report
CATC	Continuous Automatic Train Control
CBD	Central Business District
CBTC	Communication Based Train Control
CENELAC SIL-4	European Standard – Safety Integrity level four
CNCR	Central National Capital Region
CRC	Consultancy Review Committee
DAMEL	Delhi Airport Metro Express Line
DFC	Dedicated Freight Corridor
DGRA	Delhi-Gurgaon-Rewari-Alwar
DIMTS	Delhi Integrated Multi Model Transport Services
DMIC	Delhi Mumbai Industrial Corridor
DMRC	Delhi Metro Rail Corporation Limited
DPR	Detailed Project Report
DTC	Delhi Transport Corporation
DTS	Data Transmission System
EMU	Electro-motive Units
HVAC	Heating, Ventilation and Air Conditioning
IR	Indian Railways
ISBT	Inter State Bus Terminus
KMP	Kundli-Manesar-Palwal
LMV	Light Motor Vehicle
MBIR	Manesar-Bawal Investment Region
MOU	Memorandum of Understanding
MOUD	Ministry of Urban Development

MRTS	Mass Rapid Transit System
NATM	New Austrian Tunnelling Method
NCR	National Capital Region
NCRPB	National Capital Region Planning Board
NCRTC	National Capital Region Transport Corporation
NCTD	National Capital Territory Delhi
NDLS	New Delhi Railway Station
NH	National Highway
NZM	Nizamuddin
OCC	Operations Control Centre
OFC	Optical Fibre Cable
PHPDT	Peak Hour Peak Direction Trips
RDSO	Research Design and Standards Organisation
Rajiv Chowk (G)	Rajiv Chowk (Gurgaon)
RFID	Radio Frequency Identification Device
ROW	Right of Way
RRTS	Regional Rapid Transit System
SDH	Synchronous Digital Hierarchy
SEZ	Special Economic Zones
SH	State Highway
SNB	Shahjahanpur – Neemrana – Behror – Complex
TO	Train Operator
TOD	Transit Oriented Development
TSS	Traction Sub Station
UMTC	Urban Mass Transit Company Limited

1. Introduction

1.1. Study Background

Figure 1-1 National Capital Region

The National Capital Region Planning Board (NCRPB), in order to enhance the connectivity within the National Capital Region, has proposed to connect the Urban, industrial (SEZs/industrial parks), regional and sub-regional centers through a Regional Rapid Transit System (RRTS). The Integrated Transportation Plan 2032 has identified eight rail based rapid transit corridors to enhance the efficacy of the transportation system in the NCR (Figure 1-1) in addition to providing other facilities including road network enhancements.

The eight identified RRTS corridors are:

1. Delhi – Gurgaon – Rewari – Alwar [DGRA - Project Corridor]
2. Delhi – Ghaziabad – Meerut
3. Delhi – Sonipat – Panipat
4. Delhi – Faridabad – Ballabhgarh – Palwal
5. Delhi – Bahadurgarh – Rohtak
6. Delhi – Shahadra – Baraut
7. Ghaziabad – Khurja
8. Ghaziabad – Hapur

The proposed RRTS corridors are shown in Figure 1-2

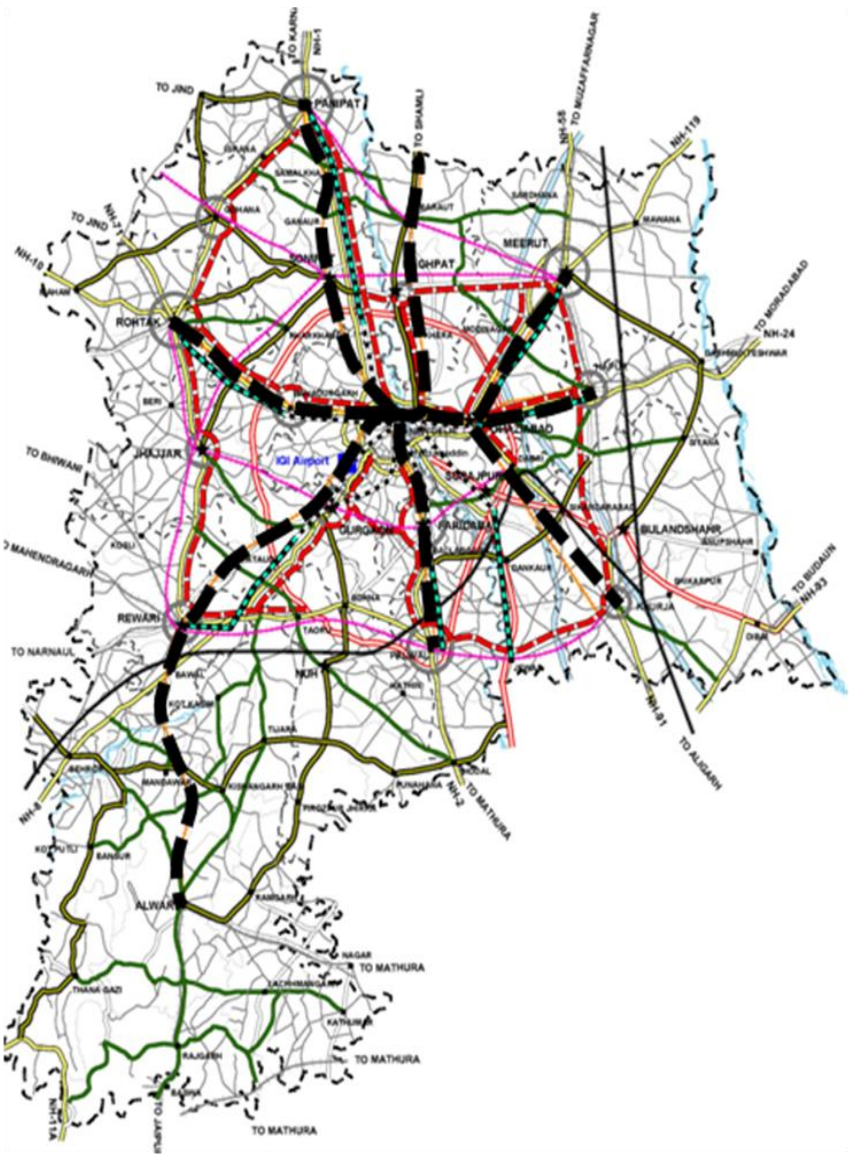


Figure 1-2 National Capital Region and Proposed RRTS corridors

The Feasibility Report on the Delhi –Alwar RRTS corridor was submitted on 27.09.2011 and was approved as per the minutes of the Consultants Review Committee (CRC) meeting held on 14.10.2011. Minutes of the meeting is attached as Annexure 1.

The observations and decisions were summarised as follows:-

(i) Consultant should check the alignment at Dharuhera, Rewari and Bawal and modify, if found conflicting with Master Plan.

(ii) Land Cost taken for financial analysis need to be revised based on prevailing rates.

(iii) The amount due as Central Taxes would be treated as interest free subordinate debt to be shared between the Central and the State Government. The State Taxes shall be waived off/reimbursed by the States.

(iv) Contribution of project cost should not be taken as 12.5%. It is equity contribution just to form the company. It should be decided on the basis of length of RRTS corridor in the State and benefits thereon.

(v) Committee approved the Feasibility Report and directed to release the payment. The Committee directed to submit the addendum on Feasibility Report after incorporating the above suggestions.

1.2. Scope of the Addendum Report

This Addendum to the Feasibility Report addresses the points as directed by the CRC tabulated below

S. No.	Decisions	Inclusion in the Addendum
1	Consultant should check the alignment at Dharuheda, Rewari and Bawal and modify, if found conflicting with Master Plan.	The changes in the alignment suggested by the Govt. of Haryana have been discussed with Sr. Town Planner, Gurgaon and District Town Planner, Rewari on 09.11.2011, and further with Sh. S.S. Dhillon, Financial Commissioner and Pricipal Secretary, Town and Country Planning alongwith other officers of Govt. of Haryana on 22.11.2011, and the suggested alignment is marked on the key map in Figure 1-3. It was also decided in these meetings that Rajiv Chowk and MBIR stations, approved earlier, may be deleted. Kherki Dhaula station will be added between the meeting points of NPR and SPR at NH-8.

S. No.	Decisions	Inclusion in the Addendum
		Thus, there is a suggested change of around 35 kms in the alignment (kindly refer letter No. UMTC/GPG/RRTS/NCRPB/144 dated 22.12.11 and letter No. UMTC/GPG/RRTS/NCRPB/146 dated 26.12.11 attached as Annexure 2. However, no directions have been received from NCRPB on the work involving the change in alignment in Haryana and ***hence this report contains the financial analysis and work based on the RRTS alignment approved by the CRC and Task Force on 17.03.11 and 29.06.11 respectively.***
2	Land Cost taken for financial analysis need to be revised based on prevailing rates.	The Circle rates have been collected and included in the land cost calculations in the costing in Chapter 3
3	The amount due as Central Taxes would be treated as interest free subordinate debt to be shared between the Central and the State Government. The State Taxes shall be waived off/reimbursed by the States.	This has been considered in the revised Financial Analysis in Chapter 4
4	Contribution of project cost should not be taken as 12.5%. It is equity contribution just to form the company. It should be decided on the basis of length of RRTS corridor in the State and benefits thereon.	This has been rectified. The state wise contribution of project cost would be decided by NCRTC as per the minutes of meeting held on 14.10.11.

This Report contains the revised Financial Analysis after including all the necessary changes as discussed in the CRC meeting held on 14.10.11.

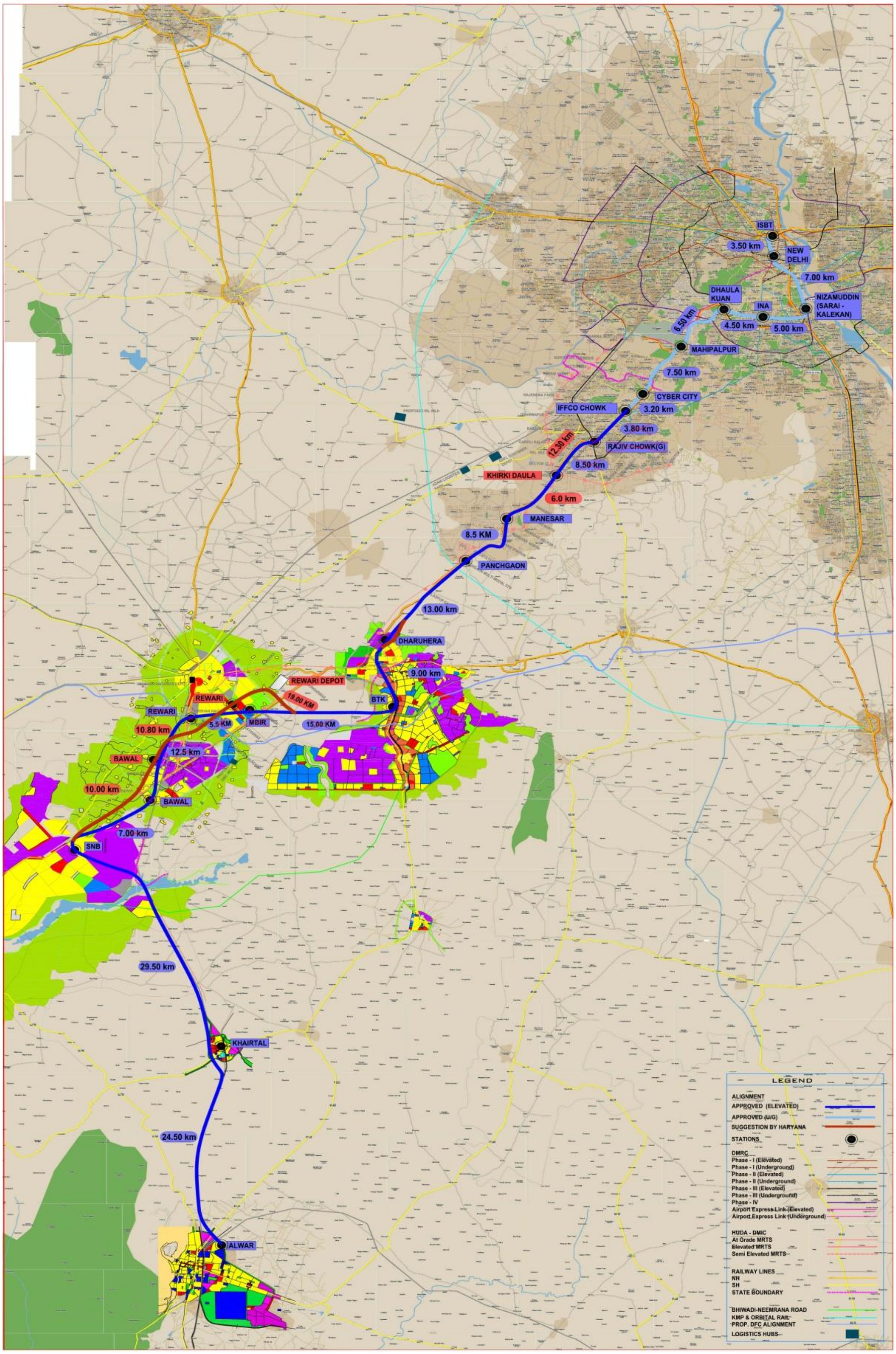


Figure 1-3 Key Map

2. Travel Demand Forecast

2.1. Introduction

The traffic studies for identifying the recommended alignment and forecasting the future traffic for the alignment was carried out based on primary and secondary data collection. The transport planning process primarily consists of development of a set of formulae / equations which are referred as models, enabling forecast of future travel demand and traffic characteristics. It is not just one model but a series of interlinked models of varying levels of complexity dealing with different facets of travel demand. Planning variables at zonal level, such as population, employment, land use and transit oriented development have been made use of in the transport demand analysis.

The finalised Alignment as approved by the CRC and Task Force consists of the following stations:-

ISBT Kashmere Gate - New Delhi Railway Station – Sarai Kale Khan (Nizammuddin) – INA – Dhaula Kuan – Mahipalpur – Cyber City – IFFCO Chowk - Rajiv Chowk (G) – Manesar – Panchgaon – Dharuhera – BTK – MBIR – Rewari – Bawal – SNB – Khairthal – Alwar.

The traffic forecast has been carried out for this alignment taking into account the influence on RRTS traffic due to the connectivity of the zones connected by the DAMEL and the DMRC Gurgaon Line. The details of the travel demand and traffic characteristics have been provided in the sections below.

2.2. Results

The alignment is shown in **Figure 2-1**. The ridership results are presented in the following sub sections.

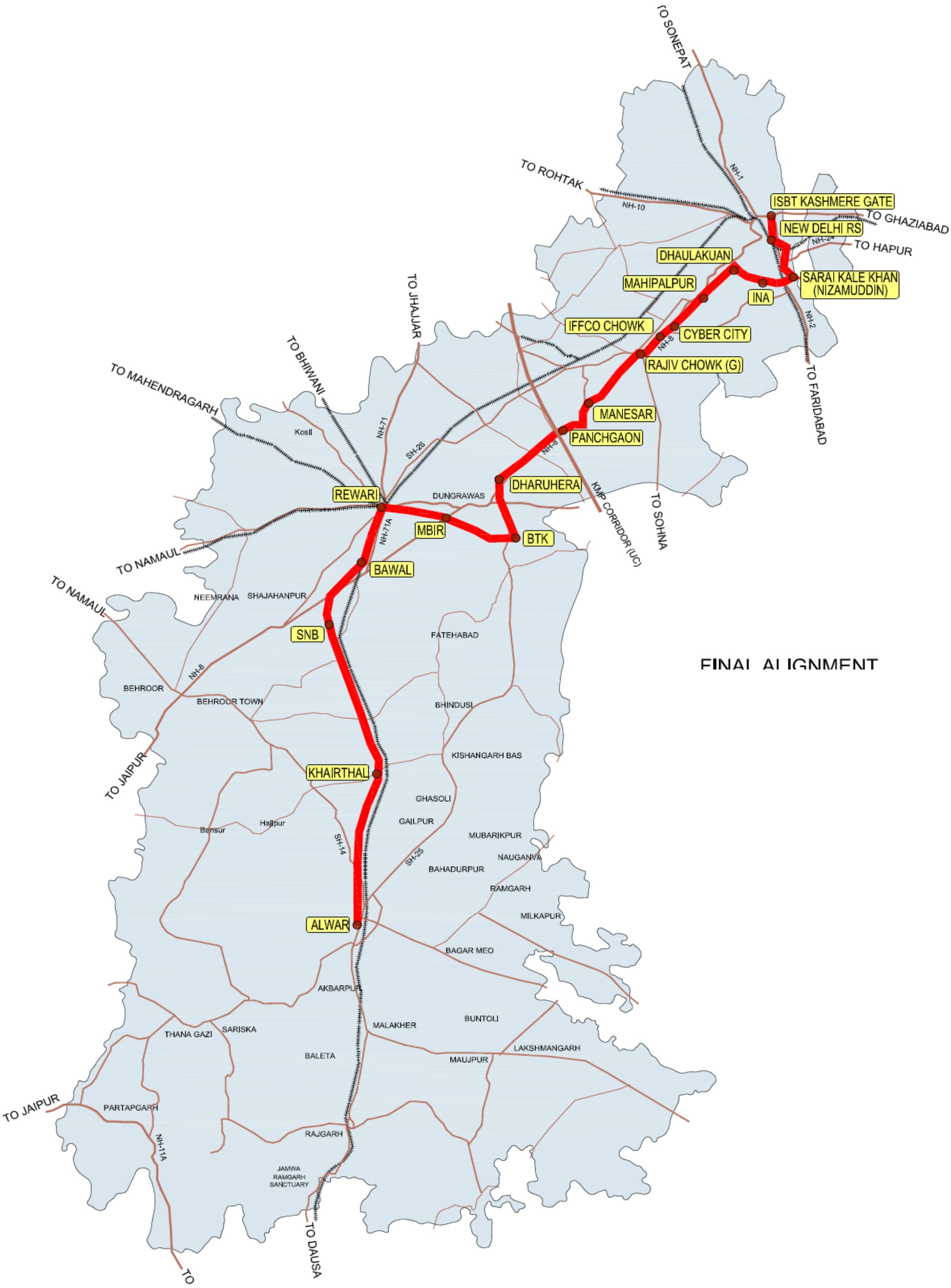


Figure 2-1 – Final alignment

The peak hour candidate trips and diverted trips for 2016, 2021, 2031 and 2041 with TOD are presented in Table 2-1.

Table 2-1: Peak Hour Candidate trips, diverted trips

Mode	Peak Hour Candidate trips	Peak Hour Diverted Trips
2016	979738	69920
2021	1247178	91321
2031	1515061	125593
2041	1798448	151135

2.3. Station wise Boarding and Alighting

The daily ridership on the proposed corridor will have an important impact on the feasibility of the project since the revenue generation will depend mostly on the number of people using the facility; this has been forecast by detailed model development and calibration. The daily boarding and alighting at each station is considered to be equal.

The daily boarding-alighting on RRTS for the various horizon years are given in Table 2-2.

Table 2-2: Daily Boarding/Alighting for various stations in RRTS

S.No	Station Name	2016	2021	2031	2041
1	ISBT Kashmere Gate	20390	24540	33095	44340
2	New Delhi RS	26030	32855	42495	54280
3	Sarai Kale Khan (Nizamuddin)	38000	44520	66395	84950
4	INA	24955	31275	47545	55515
5	Dhaulakuan	6000	9270	10140	11565
6	Mahipalpur	66035	87320	131110	145720
7	Cyber City	58210	83760	114145	125675
8	IFFCO Chowk	44760	44655	57535	67105
9	Rajiv Chowk (G)	25285	47105	57035	67145
10	Manesar	46765	61085	87410	96520
11	Panchgaon	24785	34290	38715	44440
12	Dharuhera	29375	33995	40680	45000
13	BTK	59395	76510	93535	115185
14	MBIR	24625	28865	34960	48050
15	Rewari	68000	99795	140735	161165
16	Bawal	62980	82240	135835	167035
17	SNB	38805	46915	61205	93305
18	Khairthal	18615	23155	32150	39285
19	Alwar	15320	20340	30690	44380
	Total	698330	912490	1255410	1510660

2.4. Final summary

Ridership summary for the RRTS is presented in Table 2-3.

Table 2-3: Ridership for various Horizon Years (Realistic Scenario)

Description	2016	2021	2031	2041
Peak Hour Candidate Trips	979738	1247178	1515061	1798448
Peak Hour Diverted Trips	69920	91321	125593	151135
Daily Ridership on RRTS	698330	912490	1255410	1510660
Maximum sectional load	13792	15646	21817	25775

The rolling stock requirement and the train operation plans for the horizon years have been worked out on the basis of this above data. The revenue generation has also been worked out based on the above figures.

3. Cost Estimates

3.1. INTRODUCTION

Project Cost estimates for the RRTS Delhi-Gurgaon-Rewari-Alwar corridor as mentioned below have been prepared covering civil, electrical, signaling and telecommunication works, rolling stock, environmental protection, rehabilitation, considering 25KV AC traction at January 2012 price level, both for Capital and Operation & Maintenance costs.

While preparing cost estimates, various items have generally been grouped under three major heads on the basis of:-

- Route km length of alignment
- No. of units of that item
- Item being independent entity

All items related to alignment, whether in underground or elevated or at grade construction, permanent way OHE, signaling and telecommunication, have been estimated on rate per route km/km basis. Route km cost for underground alignment construction, excludes station lengths. Station lengths (320m) have to be done by tunneling technique. The rates adopted for underground stations include cost of civil structures and architectural finishes. Similarly, cost of elevated and at grade stations includes civil work for station structures, architectural finishes, platform roofing, etc. Provisions for electrical and mechanical works, air conditioning, lifts, escalators, etc, have been worked out separately. These rates do not include cost of permanent way, O.H.E., power supply, signalling and telecommunication, automatic fare collection (AFC) installations, for which separate provisions have been made in the cost estimates. Similarly, for other items like Rolling stock, Traction & Power, tunnel ventilation, etc, costs have been summed up separately. In remaining items, viz. land, utility diversions, rehabilitation, etc the costs have been assessed on the basis of each item taken as an independent entity.

The overall Capital Cost for the corridor at January 2012 price level works out to Rs.24600 crores including the cost of rolling stock for the induced traffic, excluding applicable Taxes & Duties but including cost of land. Taxes and duties have been added @20% of the cost (excluding land cost) for working out the financial viability. The base rates of Delhi Metro Phase III estimate of January 2011 have been adopted, which have been suitably modified for the RRTS infrastructure and have been escalated further for one year@ 5% per annum.

Details and methodology of arriving at these costs are discussed in the following paragraphs.

3.2. Civil Engineering Works

Land requirements have been kept to the barest minimum and worked out on area basis. Acquisition of private land has been minimized as far as possible.

For underground alignment, no land is proposed to be acquired permanently, except small areas for locating entry/ exit structures, ventilation shafts, traffic integration etc. Elevated alignment is proposed to be located on the road verge, side of roads and wherever, this is outside the road alignment, minimum land area about 15m wide is proposed for acquisition for the piers and the service road. Land will be required at stations locations.

The land proposed for Transit Oriented Development (TOD) has been reduced to 377 hectares in the Haryana and Rajasthan stations from an earlier estimate of 518 hectares, this has been done based on the discussions with Haryana Govt on 22.11.2011 and subsequent discussions to minimize land acquisition.

Cost of Govt. land is based on the rate presently being charged by the concerned authorities, such as L&DO, MCD, DDA, etc. and circle rates for the rest of the areas.

Provision for cost of land required for resettlement and rehabilitation has been made in the cost estimates.

In addition to the lands required permanently, some areas of land (mainly Govt.) are proposed to be taken over temporarily for construction yards.

3.3. Permanent Way

For underground and elevated alignment ballastless track and for depot, ballasted track is proposed. Rates adopted are based on the DPR cost of similar works in Phase-III DMRC MRTS duly updated to the price level of January 2012,

3.4. Utility Diversions, Environmental Protection, Miscellaneous Other Works

Provisions have been made to cover the cost of utility diversions, miscellaneous road works involved, road diversions, road signages etc. and environmental protection works on lump sum basis.

3.5. Rehabilitation and Resettlement

Provisions have been made on fair assessment basis, to cover cost of relocation of Jhuggies, Shops, residential houses on private land etc.

Provision for barracks for CISF including security equipment and Quarters for O&M staff has been made in the cost estimates.

3.6. Traction and Power Supply

Provision has been made to cover the cost of O.H.E., Auxiliary sub stations, receiving substations, service connection charges, SCADA and miscellaneous items, on route km basis separately for underground alignment, elevated and at-grade section as the requirements are different and costs are more for underground section.

Provisions towards cost of lifts, escalators for underground and elevated stations have been made in the cost estimates. Rates are based on the DPR cost of similar works in Phase-III DMRC MRTS duly updated to the price level of January 2012. Provision for mid section shaft is made separately.

3.7. Signalling And Telecommunication Works

Rates are based on the DPR cost of similar works in Phase-III DMRC MRTS duly updated to the price level of January 2012. These rates include escalation during manufacturing and supply of equipment and their installation at site. Lump sum Cost of Platform Screens Doors (PSD) for the underground stations has also been added in the estimate.

3.8. Automatic Fare Collection

Adopted rates are based on the DPR cost of similar works in Phase-III DMRC MRTS duly updated to the price level of January 2012

3.9. Rolling Stock

Adopted rates are based on the DPR cost of similar works in Phase-III DMRC MRTS and DAMEL rolling stock cost duly updated to the price level of January 2012 considering likely increase due to increase in coach dimensions (24mx3.66m) and the operating speed.

3.10. General Charges and Contingencies

Provision @3% has been made towards general charges on all items, except cost of land, which also includes the charges towards Detailed Design Charges (DDC), etc. Provision for contingencies @3% has been made on all items including general charges.

3.11. Capital Cost

The overall Capital cost for these corridors estimated at January 2012 price level, based on the above considerations works out to Rs.24600/- crores.

Table 3-1 shows the Cost Break up for the RRTS corridor

Table 3-1: Cost Break up

S.No.	Item	Unit	Rate based on DMRC Rates of Ph-III of Jan. 2011 escalated @5% for 2012 (in Crore)	Qty.	Amount (in Crore)
1.0	**Land**				

S.No.	Item	Unit	Rate based on DMRC Rates of Ph-III of Jan. 2011 escalated @5% for 2012 (in Crore)	Qty.	Amount (in Crore)
1.1	Land in Delhi State required for underground stations for integration with DMRC, RRTS and Northern Railway; exit and entry for underground station and ventilation shafts	Hect.	varies from 164 Cr. to 300 Cr. per ha	2.00	413.00
1.2	Land in Haryana required for elevated station including TOD elevated section between Cyber City and Bawal and Depot at MBIR.	Hect.	2.20 Cr. (Avg.)	334	731.00
1.3	Land in Rajasthan required for elevated station with TOD, elevated station between Bawal-SNB to Alwar and Depot and Alwar.	Hect.	0.7 Cr. (Avg.)	309	218.00
1.4	Temporary land for casting yard, working spares.	Hect.	0.50	225	113.00
	Sub Total (1.0)				**1475.00**
2.0	**Alignment and Formation**				
2.1	Underground section - Tunneling by TBM	R. Km	166.00	36	6049.04
	Elevated viaduct section	R. Km	32.55	141	4589.55
	Special span	R. Km	31.00	1.00	31.00
	Civil Work for mid section ventilation shaft	Each	3.00	20	60.00
	Sub Total (2.0)				**10729.59**
3.0	**Important Bridges**				
	Length of Sahibi River = 0.700 km	Nos.	30.00	1.00	30.00
	Sub Total (3.0)				**30.00**
4.0	**Station Buildings;**				
4.1 (a)	Underground Station	Each	178.24	7.00	1248.00
(b)	Underground Terminal Station	Each	250.00	1.00	250.00
4.2	Elevated Station (including finishes)				
(a)	Way side station	Each	37.80	9.00	340.20
(b)	Terminal station	Each	40.32	2.00	80.64
4.3	Interchange facilities at interchange station viz ISBT, New Delhi, Sarai Kale Khan, Dhaula Kuan, Mahipalpur, Cyber City & IFFCO Chowk	Each	10.00	7.00	70.00
	Sub Total (4.0)				**1988.84**
5.0	**E & M Works**				

S.No.	Item	Unit	Rate based on DMRC Rates of Ph-III of Jan. 2011 escalated @5% for 2012 (in Crore)	Qty.	Amount (in Crore)
5.1	Underground station (E&M, Lifts, Escalators, DG Sets, UPS, TVS, ECS etc.)	Each	58.00	8.00	464.00
5.2	Elevated station (E&M, Lifts, Escalators, DG Sets etc.)	Each	6.86	11	75.00
5.3	Mid section ventilation shafts	Each	6.00	20	120.00
	Sub Total (5.0)				**659.00**
6.0	**Depot**				
	Depot of Sarai Kalekhan, MBIR and Alwar (including Civil Works, E&M, P&M, Track works, OHE etc.)	L.S.			200.00
	Sub Total (6.0)				**200.00**
7.0	**Permanent Way**				
	Ballast less/Ballasted Track for elevated, underground and at grade alignment	R. Km	6.80	183	1245.00
	Sub Total (7.0)				**1245.00**
8.0	**Traction and Power**				
	Traction and power supply including OHE ASS etc.				
	Underground section	R. Km			
	Elevated & Grade section	R. Km			
	Sub Total (8.0)				**846.00**
9.0	**Signalling and Telecom**				
9.1	Signalling	R. Km	10.22	183.00	1781.00
9.2	Telecom	Each	4.58	19.00	87.00
9.3	Auto Fare Collection				
9.3.1	Underground station	Each	3.11	8.00	25.00
9.3.2	Elevated Station	Each	3.11	11.00	33.00
9.4	PSD at Station	L.S.			20.00
	Sub Total (9.0)				**1946.00**
10.0	**Rolling Stock (BG)**	Each	13.60	264	3590.00
	Sub Total (10.0)				**3590.00**
11.0	**Utilities**				
11.1	Misc. utilities, other Civil works, such as median, road signages, Electrical & Telecom utilities.	L.S.			150.00

S.No.	Item	Unit	Rate based on DMRC Rates of Ph-III of Jan. 2011 escalated @5% for 2012 (in Crore)	Qty.	Amount (in Crore)
11.2	Service roads	Km	1.10	70	77.00
	Sub Total (11.0)				**227.00**
12.0	R&R including Hutments and road restoration etc.	L.S.			200.00
	Sub Total (12.0)				**200.00**
13.0	Barracks for CISF including security equipments and staff quarters for ORM staff.	L.S.			40.00
	Sub Total (13.0)				**40.00**
14.00	Special noise & vibration reduction treatment	L.S.			**50.00**
	Sub Total (14.0)				**50.00**
15.00	Total of all item except land				21751.43
16.00	General charges including design charges @3% on all items except land.				653.00
17.00	Total including General Charges.				22404.43
18.00	Total cost including of land cost.				23879.43
19.00	Contingencies @3%.				716.00
	Gross Total				**24595.43**

4. Financial Analysis

4.1. Introduction

Full recovery of capital investment from public transport systems has usually remained elusive considering the huge investments required. Thus higher emphasis is given to operational sustainability for this kind of projects. Such capital intensive projects hugely affect socio economic dynamics at the regional level and therefore necessity of such projects could be justified through Socio-Economic Cost benefit analysis which is discussed separately in the chapter on the same.

This chapter attempts to estimate the extent of financial viability and operational sustainability of proposed RRTS project. It discusses inputs and estimations related to project cost, means of finance, revenues, and operations cost. Alternative implementation formats including PPP formats are also analyzed and discussed.

4.2. Analysis Period and Sequence

It is expected that the project construction period would be five years upto Dec 31, 2016. The operations are expected to begin under this assumption on Jan 1, 2017. The period of operations used for the purpose of financial analysis is 30 years thereafter upto 2046. The revenues, expenses, taxes, profits and cashflow are calculated for this time window.

The financial analysis for RRTS begins with analysis of the project in totality without considering the implementation model and agency. The discussion proceeds with estimations of project cost, various streams of revenue, Operation and maintenance cost and analysis of operational viability and returns of the project.

At the end of above analysis, various implementation models for the project are discussed. Suitable model for development and implementation is recommended taking the pros and cons of each model in to consideration.

4.3. Project cost

The summary of estimated project cost used for financial analysis is presented in Table 4-1.

Table 4-1: Summary of project cost

Particular	Total (*Rs. Crore)*
Land	1475
Government land	*1317*
Private Land	*159*
Aggregate Project Cost except land	21751
Total Project Cost with Land	**23227**
General Charges inc. Design (3% on all items except land)	653
Total with General Charges	**23879**
Contingency on all items at 3%	716
Project Cost with Contingency	**24596**

Source: As per Project cost estimates

The above cost does not include tax on project goods and interest during construction. These are introduced subsequently in the analysis as per the requirement of the context. However project cost is escalated due to inflation during construction period as follows.

Estimated construction period is around five years. Construction is expected to end on December 2016. The project cost is escalated to account for increase in construction cost over the period. The table 4-2 shows the escalated project cost over five years. The project cost is escalated at 6% pa considering average growth in Wholesale Price Index published by Government of India.

Table 4-2: Phasing of Project cost with escalation

Construction Phasing (*Rs. Crore)*	2012 10%	2013 20%	2014 30%	2015 30%	2016 10%	Total 100%
Project Cost (Un-escalated)	2460	4919	7379	7379	2460	24596
Project Cost (Escalated)	2607	5527	8788	9315	3291	29529
Tax on Project Goods	231	489	777	824	291	2611
Total	2838	6016	9565	10139	3583	32141

Source: Author's estimations

The applicable combined taxes from Central and State Governments are estimated to be around 20% of the total hard cost. The tax rates are adopted on the basis of tax rates estimated in other metro rail projects in India. However as per clause 3.3 of the MOU which is signed between MOUD, NCPRB and State Govt. of Delhi (GNCT), Rajasthan, Haryana and Uttar Pradesh, the Central taxes for RRTS project would be considered as interest free subordinate debt while State Govt. Taxes would be waived off/reimbursed. Thus, the above calculation includes only applicable Central taxes at around 10% on the hard cost arrived at by excluding land cost, general and design charges and contingencies. The tax amount considered as sub-debt from the Government would be repaid in a shared manner to the Central and State Government. As per the MOU, the land cost would also be considered as interest free subordinate debt from the state Governments. However such arrangements are considered in the discussion on the implementation models in the later part.

It can be seen that there is an increase of around 31% in the aggregate project cost by the end of the construction period.

Estimations related to revenue and O&M expenses are discussed further.

4.4. Estimations of Operations and Maintenance Cost

The Operation and Maintenance (O&M) cost for RRTS is segregated into five components like 1) Staff Salary 2) Repair and Maintenance expenses 3) Administrative expense 4) Replacement Expenses 5) Energy Expenses 4). The O&M cost for RRTS is calculated mainly using cost of similar metro type rail systems.

Staff salary

Staff requirement is considered to be 35 persons per km. Thus total estimated staff required for RRTS would be thus 6300 persons. Following is the estimate of the breakup of the staff requirement and estimated salary, shown in table 4-3.

Table 4-3: Break up of Staff and Salary

Designation	No. of persons required	Annual Remuneration CTC basis (Rs. Lakh)	Total remuneration (Rs crore)
CEO	1	50	0.50
Vice Presidents	10	24	2.40
Dept. Heads	40	12	4.80
Middle level	320	10	32.00
Technician/Supervisory Level	1300	5	65.00
Others	4629	2.5	115.73
Total	**6300**		**220.43**

Source: Discussion with Manpower agencies regarding prevailng remuneration levels in similar kind of jobs.

The above remuneration levels are at 2011 prices. These are escalated over 6 years for equivalent levels in 2017. The growth under this head is estimated to be 9% pa.

Repair and Maintenance Expenses

Repair and Maintenance Expenses including cost of inventory for RRTS are expected to be around Rs. 0.9 crore per km. The cost is escalated at 6% pa.

Administrative Expenses

Administrative expenses are estimated in table 4-4.

Table 4-4: Administrative Expenses

Admin Expenses	Rs Crore
Insurance, legal, stationary, telephone, security, vehicle hire & maintenance, land license fee, loss on asset etc. (Rs lakh Cost per km)	25.00
Above Cost in Rs. Crore for RRTS	45.00
Travelling and conveyance etc pa. Rs crore	1.00
Misc pa (Rs crore)	5.00
Total	**51.00**

Source: Author's Estimations

Replacement Expenses

The replacement costs are calculated based on 10% replacement for project goods after 20 years of operations. The project goods which will be required replacement are shown in table 4-5:

Table 4-5: Project goods to be considered for replacement

Project Goods	Cost (Rs. crore)
E & M Works	659
Permanent Way	1245
Traction and Power	846
Signaling and Telecom	1947
Utilities	227
Special noise & vibration reduction treatment	50
Total	**4974**

In addition to above rolling stock would be purchased and replaced periodically as shown in table 4-6.

Table 4-6: Purchase of rolling stock

	2021	2031	2041
Number of units (Cumulative)	318	396	477
Number of units (Incremental)	54	78	81
Estimated Cost Per Unit (Rs Crore)	24	44	78
Purchase of Rolling stock (Rs. Crore)	1315	3402	6327

Source: As per the rolling stock requirement calculated for the project.

The cost for rolling stock at the beginning of operations is already included in the project cost. Purchase Cost for rolling stock units for the future years are obtained by escalating existing prices.

Energy Expenses

The energy expenses are a product of units of electricity consumed for traction and buildings and the per unit cost of consumption. Table 4-7 shows the estimated consumption of electricity for the entire system of 180 kms.

Table 4-7: Energy Expenses

Unit Consumption (Crore Units pa)	2016	2021	2031	2041
For Traction	53.04	63.22	79.66	94.96
For Auxiliary	14.18	14.18	19.31	19.31
Total	**67.22**	**77.4**	**98.97**	**114.27**

Source: As per the estimated energy consumption pattern

The unit price for electricity for RRTS is estimated to be a concessional rate of Rs. 4/ unit. The tariffs are envisaged to increase 5% annually during the projection period.

Following is the summary of estimated O&M expenses over the next 30 years shown in table 4-8.

Table 4-8: Summary of O&M expenses

Sr. No	Particular	2017	2021	2031	2036	2041	2046
		Rs .in Crore					
1	Staff Salaries	220	311	737	1133	1744	2683
2	Repair & Maintenance Exp	162	205	366	490	656	878
3	Energy Expenses						
	Unit Consumption (Unit crore)	67	77	99	99	114	114
	Unit Price (Rs. Unit)	5.36	6.21	9.63	11.70	14.22	18.15
	Total Energy Expenses	360	480	953	1158	1625	2074
4	Admin Expenses	51	64	115	154	206	276
5	Replacement in Equipment /Addition of Rolling Stock	0	1315	3402	1595	6327	0
	Total	**794**	**2376**	**5573**	**4212**	**10558**	**5911**

Source: Author's Estimations

It can be seen that staff salary and energy expenses are the significant contributors to O&M costs. The replacement in equipment and addition to rolling stock takes place only at certain intervals, which happen to be the years mentioned above.

4.5. Estimations of Revenue

Urban transit projects lead to a number of benefits to users of the system. The benefits are both direct and indirect in nature. Direct benefits include availability of transit service, opportunities for advertising at transit stations, and opportunities to provide products/services through kiosks/outlets at stations. Indirect benefits arise from association with the project through proximity or through significant positive externalities. The following table 4-9 shows the nature of benefit and their value capturing possibilities.

Table 4-9: Revenue Capture Instruments for different benefits associated with RRTS Project

Nature of Benefit	Revenue Capture Instrument	Status of capture
Direct	• Fare Box • Advertising • License Fees from station assets	Captured in terms of fare, advertisement revenue and license fee from kiosks, stalls and other assets
Proximate	• Increase in business next to stations • Real Estate Development Rights arising from ToD. • Rise in property value around stations	Captured from property development near stations for TOD
Indirect	• Economic Development on the corridor • Less congestion for road users • Improvement in air quality • Availability of more public space • Reduction in use of fossil fuels	Captured from revenue from carbon credits. Cess on Property Transaction and Cess on VAT in the states also considered.

Source: Author's Analysis

It can be seen in the above table that direct benefits play a major role in revenue generation while indirect benefits are relatively difficult to capture. Capturing indirect benefits often require concerted action not only at the project level but assume the cooperation and action from institutions involved such as local bodies, regional Government and members of the public receiving the indirect benefits. This is so since indirect benefits follow from non-excludability (meaning it is difficult to exclude those who do not pay for receiving the benefits).

The principal source of revenue for the project is fare revenue. However since such revenue would be insufficient for recovery of capital in a project of this magnitude, property development near the stations in the spirit of developing Transit Oriented Development (TOD) is proposed. This income supports the fare income in a significant manner, though is phased over a long period of time given that development will happen along the corridor only gradually. Further, it has been attempted to capture value from proximity benefits through carbon credits.

The sources of revenue for the project are the following: 1) fare box collection 2) Income from TOD 3) advertisement fees, 4) license fees from stalls within the station premises and 5) sale of Carbon Credit (CC). Estimations related to fare box collection is discussed first. It is expected that commercial operation would start from 1st January, 2017. Revenue is thus projected for next 30 years therafter.

Fare box collection

Following table 4-10 shows passenger traffic forecast upto 2046 with realistic, optimistic and pessimistic scenarios.

Table 4-10: Projected daily traffic

Daily Traffic (In lakh)					
Scenarios	**2016**	**2021**	**2031**	**2041**	**2046**
Realistic	6.99	9.12	12.55	15.10	16.27
Optimistic	8.06	10.38	14.18	16.98	18.30
Pessimistic	5.96	7.78	10.69	12.79	13.78

Source: Traffic Demand Analysis for RRTS

Average trip length is estimated to be shown in table 4-11;

Table 4-11: Average trip length

Year	2016	2021	2031	2041
Average Trip Length (km)	27.42	25.96	27.69	28.78

Source: Traffic Demand Analysis for RRTS

The average trip length is increasing over time as the passengers are estimated to commute for longer distance.

Estimation of Fares

A mix of distance based flat and distance based increasing fares are adopted. In order to determine the fares, fare fixation principles have been evolved as follows:

1) Affordability to the users
2) Sustainability of the system
3) Competitiveness with the other modes of transport on the similar route
4) Flexibility for revision

Table 4-12 shown the comparison of fares for competing transportation facilities.

Table 4-12: Fare comparison

Average fares (Rs. /Pax)@								
Stages	**DM RC**	**DTC**	**IR AC chair**	**IR Third AC 3T**	**IR Second Sleeper**	**RSRTC (Ac Service)**	**HSRTC (Ac Service)**	**Proposed Fares for RRTS**
Base fare	**8**	**5**	-	-	-	-	-	**15**
0-10	12	5	-	-	-	-	-	15
10-20	16	10	-	-	-	-	-	20
20-30	20	15	-	-	-	44	34	31
30-40			-	-	-	-	-	38
40-50			-	-	-	-	-	50
50-60			-	-	-	96	75	61
60-70			-	-	-	-	-	72
70-80			-	-	-	131	102	83
80-90			-	-	-	-	-	94
90-100			-	-	-	166	129	105
100-110			240*	210	120	-	-	116
110-120			-	210	120	-	-	127
120-130			-	-	-	219	170	138
130-140			-	-	-	-	-	149
140-150			-	-	-	-	-	160
150-160			-	-	-	271	211	171
160-170			-	-	140	-	-	182
170-180			-	-	140	-	-	193

Source: Fares of different systems and analysis

@ The fares considered above are average fares calculated for respective distance slabs

**These are Shatabdi Rates. Normal AC Chair Car Rates are Rs.165.*

The proposed fares for RRTS are maintained higher than Delhi Metro Rail and DTC buses to discourage shorter or within the city trips. The rates would be slightly higher than the IR's sleeper class but lower than IR's AC chair and 3 tier AC trains and AC services of RSRTC and HSRTC.

Proposed RRTS could compensate higher rates through faster, frequent and comfortable services in comparison with IR sleeper class and RSRTC buses. All the above transportation systems cater to the middle and long distance trips which is the target passenger segment for RRTS.

Fare Revision

The fare revision formula adopted for the RRTS is based on international practice in urban transport systems of relating the fares to the consumer's own inflation rather than input costs[1]. The fares for RRTS are thus revised biennially, indexed with Wholesale Price Index (WPI). The proposed formula for fare revision is placed below.

Revised Fare = Base Fare +[100% of Base Fare *% change of Consumer Price Index*(1-efficiency factor)]

Using the historical growth rate in WPI over last 8 years, fare is estimated to be rising at 6.5% over the projection period. Insertion of efficiency factor is optional and can be around 5%. The fare box revenue is calculated using fares applicable per passenger according to average trip length. Such fares are applied on the daily passenger traffic.

It is estimated that 60% of the daily commuters would be pass holders. It is expected that the number of pass holders would not be as high as in a metro situation since this is a regional service. Approx 25% concession on fare is taken for the pass holders[2]. Following table 4-13 is the estimated fare box collection.

Table 4-13: Estimated fare revenue

Particular	2017	2021	2031	2041	2046
Daily Passenger (In lakh)	7.37	9.12	12.55	15.10	16.27
Daily pass holders (In Lakh)	4.42	5.47	7.53	9.06	9.76
Daily revenue from Non Pass holders (Rs. Crore)	1.38	2.19	5.66	12.78	17.72
Daily revenue from Pass holders (Rs. Crore)	1.55	2.47	6.37	14.38	19.93
Daily fare box collection (Rs. Crore)	**2.93**	**4.66**	**12.03**	**27.17**	**37.65**
Annual fare box collection (Rs. Crore)	**995**	**1583**	**4090**	**9237**	**12801**

Source: Author's Estimation

Estimations for property development through Transit Oriented Development principles are discussed further.

[1] The Singapore MRT System indexes fares revisions to changes in Consumer Price Index and in Wage index in equal proportion. It also uses an indexation factor of 1.5%.

[2] The concession of 25% to pass holders is provided in Airport Express Link project (i.e New Delhi Railway station to Delhi Airport). Similar concession rate is adopted for analysis in RRTS project.

Revenue from property development

As discussed earlier, in order to promote Transit Oriented Development (TOD), development of property along the corridor or at nodes is envisaged by acquisition of land in advance. Such development contributes to a compact city and regional development. Commuters travel from homes to workplaces through an integrated transit system (mix of main and feeder transportation systems). It reduces the travel demand in other part of the city as the origin and destinations are located on the same transport corridor. It results into dense city/region/corridor which is a better proposition as far as urban planning is concerned.

TOD property would be developed and sold on the nodes/stations of the proposed RRTS. It would be a mix of office- retail and residential spaces. Following table shows proposed TOD on RRTS corridor which is proposed to be developed on different stations.

Table 4-14: Estimated TOD

Sr. No.	Station Location	BUA (Sq.mtr)		
		Commercial	Residential	Total
1	ISBT Kashmere Gate	28672	0	28672
2	New Delhi	0	0	0
3	Nizamuddin /ISBT Sarai KaleKhan	28672	0	28672
4	INA	28672	0	28672
5	Dhaulakuan	0	0	0
6	Mahipalpur	28672	0	28672
7	Cyber City	0	0	0
8	IFCCO Chowk	0	0	0
9	Rajiv Chowk	28672	0	28672
10	Manesar	142016	0	142016
11	Panchgaon	519008	0	519008
12	Dharuhera	293216	174496	467712
13	MBIR	179200	224000	403200
14	Rewari	672672	226688	899360
15	Bawal	134400	224000	358400

Sr. No.	Station Location	BUA (Sq.mtr) Commercial	Residential	Total
16	BTK	204064	201600	405664
17	SNB	787360	883904	1671264
18	Khairthal	349216	0	349216
19	Alwar	169792	143808	313600
	Total	**3594304**	**2078496**	**5672800**
	Total (in Lakh)	**35.94**	**20.78**	**56.73**

Source: Estimation based on availability of land at different nodes and potential for development

It can be seen that the TOD is proposed mostly outside the NCR region. Around 29% of the total BUA is envisaged in SNB station followed by Rewari station (16%). Around 25% of the total BUA is jointly proposed at Panchgoa, Dharuhera and MBIR stations. Combined proportion of office and retail space in total TOD is 63% while rest is residential development.

It is understood from published sources that in 2011 combined demand for commercial and residential space in NCR was around 10 lakh sq.mtr while supply was around 6 lakh sq.mtr. The demand for 2012 is estimated to be higher than the previous year, though the actual demand would depend on the possible economic post recovery from a double dip global recession. Around 80% of the total NCR demand is anticipated from Gurgaon region alone. Considering the above the aggregate real estate demand in NCR and surrounding region for next 15-20 years can be estimated to be around 300-400 lakh sq. mtr. Owing to proposed DMIC, accessibility of Western ports and Industrial development, the Gurgaon demand is likely to spill over the proposed RRTS corridor.

Given that real estate markets are notoriously unpredictable and forecasting real estate demand is tricky, proposed TOD is estimated to be absorbed in over 20 years after operations on a conservative basis. Experience in other markets such as Navi Mumbai also support the experience of long gestation periods. Further, the proposed project line extends into areas where urban and industrial development is emerging. The real estate market demand thus will too be gradual and phased as one moves from Delhi side towards Alwar.

Thus on an average 2.8 lakh sq. mtrs of built up would available for sale in each year on an average, though actual absorption rates would vary across years. Considering the significant demand-supply gap in NCR and future scenario for development along this corridor, absorption of high volumes of property could be possible, though the phasing, annual abortion and exhaustion of all volumes as envisaged here would depend of a number of macroeconomic, regional and location related developments.

Phasing of construction and Lease of Built Up Area

It has been assumed that property absorption would be in the form of lease by developer since the properties could stand on Government land. However, given complexity arising from long gestation period for recovering capital investment through lease rentals, collection of upfront lease is proposed. Value of upfront lease is equivalent to present value of future lease rentals and hence is almost equivalent to sale values. Upfront lease would also be a preferred model if private sector developers are involved who would like to exit at some point after construction.

A lag of one year is estimated between constructions and leasing of BUA. Thus construction is also phased for 20 years. Maximum absorption occurs in the 6-12 year window after beginning of operations as industrial / urban development catches up with stations where maximum TOD is proposed. The general phasing for construction and lease is thus described below in the graph.

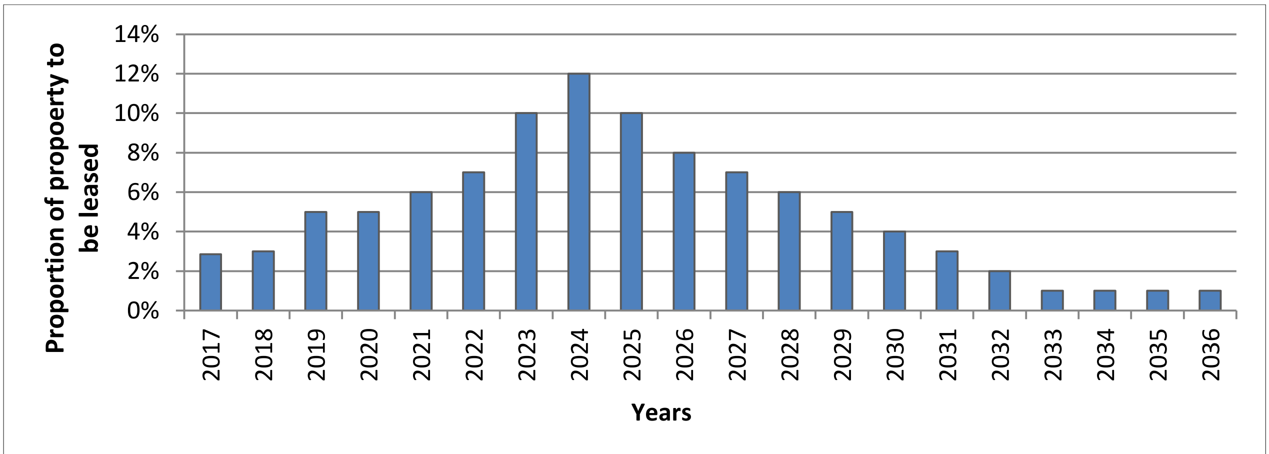


Figure 4-1: Phasing of construction and sale of BUA

Source: Author's Estimation

Construction cost

Properties at RRTS stations at Delhi and Gurgaon as well as Panchgao, Dharuhera and Alwar would be developed initially followed by MBIR and Rewari. Other stations can be developed in later stage within two years of development of above stations. The development would be cascading with spread over the years. Following is the construction cost estimated for TOD development.

Table 4-15: Estimated construction cost for TOD[3]

Construction of	Rs. Crore
Office and retail commercial space	7725
Residential space	4912
Total	**12637**

Source: Author's Estimation

Per units cost for commercial and residential development at 2011 prices is taken 11000/sq.mtr and 12000/ sq.mtr respectively. The cost is further escalated at 6% for future years. The average per unit construction cost for 20 years is calculated to be around Rs.22500/sq.mtr and Rs. 24500/sq. mtr for commercial and residential construction respectively.

Lease rates

As the TOD space is proposed to be leased out against upfront payment lease, it is equated with sale prices of property around the TOD stations. This is based on information available through published sources confirmed though verification with real estate professionals. Following are the estimated upfront lease rates for the TOD.

Table 4-16: Upfront Lease /Sale rates for TOD

Station Location	Upfront sale rates for 2011 (Rs./sq.mtr)	
	Commercial	Residential
ISBT Kashmere Gate	263620	0
New Delhi	263620	0
Nizamuddin /ISBT Sarai Kale Khan	263620	0
INA	263620	0

[3] Rates of Construction have been adopted based on discussion with developers.

Station Location	Upfront sale rates for 2011 (Rs./sq.mtr)	
	Commercial	Residential
Dhaulakuan	210896	0
Mahipalpur	210896	0
Cyber City	80700	0
IFCCO Chowk	80700	
Rajiv Chowk	80700	0
Manesar	72397	37385
Panchgaon	57917	29908
Dharuhera	50678	26170
MBIR	51402	26543
Rewari	54587	28188
Bawal	43438	22431
BTK	43438	22431
SNB	65157	33647
Khairthal	28959	14954
Alwar	36198	22431

Source: TOI Property Supplement, JLL Report, Magic Bricks.com, discussions and estimation as discussed.

The rates are considered to be increased by 10% pa. New Delhi and Gurgaon rates are used as guiding factor for sale rates at other TOD stations whenever published or reliable sources are not available. Rates for some locations are decided based on discussion with market players for suitable estimations.

The above rates are estimated to increase by 12% over the projection period in anticipation of the proposed development. Infact the prices along the DMRC corridor have already doubled. Following is the estimated net revenue from Property Development.

Table 4-17: Revenue from sale of Property

Particular (Rs. Crore)	2017	2021	2031	2036	
Commercial	844	2842	4594	2753	**82871**
Residential	229	758	1176	691	**21581**
Total	**1073**	**3600**	**5770**	**3444**	**104452**

Source: Author's Estimations

Revenue from Advertisement and Stall licensing

Revenue from advertisement is possible through display space at the stations and on the elevated corridor. Based on standard station design, available advertisement space at each RRTS station and along the corridor has been worked out as follows on an aggregate basis for all stations:

Table 4-18: Estimated Advertisement Space: Aggregate for all Stations

Sr. No	Types of advertisement	Units	Total for all stations
1	Hoardings at Platform Area	Sq.mtr	2380
2	Hoardings at Entry Area	Sq.mtr	684
3	Glow Cubes	*Nos.*	2624
4	Kiosks	*Nos.*	38
5	LED Displays	*Nos.*	76
6	Ad on Trains	Sq.mtr	6143
7	Ad on Tickets / Smart Cards	*Nos .Lakh Daily in 2017*	2.95
8	Hoardings at Parking lots	Sq.mtr	389
9	Ad on Lifts	Sq.mtr	291
10	Ad on Escalators	Nos.	38
11	Ad on the elevated corridor	Sq.mtr	26858

Source: Author's Estimations

Station wise Advertisement Space and Component wise Advertisement space is specified in Annexure 3. It can be seen that different stations differ only in terms of hoarding space.

Rates and occupancy levels for above space are based on prevailing market prices at nearest Delhi metro station and obtained through discussion with advertisement agencies holding rights to Delhi Metro spaces. The rates are escalated at 5% pa. An average 85% of the total advertisement space would be occupied throughout the projection period.

A second source of revenue is the licensing of stalls, phone booths and ATMs. Following is the aggregate commercial space for all RRTS stations based on estimated demand due to expected foot falls and station design.

Table 4-19: Aggregate commercial space at station premises

Types of Licenses	Total for all stations (Area in Sq. mtrs.)
Tea And Refreshment Stalls	2336
ATMs	920
Book Stalls	514.8
Juice Stalls	810
Milk And Milk Products Stall	570
Chemists	514.8
Phone Booth	270
Retail Kiosks	920
Parking *(No of lots)*	19

Source: Author's Estimations

It is estimated that appox. 90% of the total space would remain occupied during the projection period. The licenses would be given for one year to five years at prevailing rentals escalated at 5% pa over 30 years. Following is the proposed unit size and estimated rent for 2011 in Delhi for stall licenses.

Table 4-20: Unit size and estimated rental for stall licenses

Particulars	Size of the stalls (sq.mtr)	Rental Rs. / sq.mtr /month at Delhi (2011 prices)
Tea and Refreshment Stalls	40	750
ATMs	20	650
Book Stalls	40	750
Juice stalls	30	675
Milk and Milk products Stalls	30	675
Chemist Stalls	40	750
Phone Booths	10	600
Kiosks	20	625
Parking space (lump sum) Rs. Lakh (annual)		10

Source: Author's Estimations

Revenue from stall licensing within the station premises

Following is the summary of revenue from Advertisement and Licenses.

Table 4-21: Revenue from Advertisement and Licenses

	Particular	2017	2021	2031	2041	2046	Total	Share
A	**Advertisement Revenue**	*Rs. Crore*						
1	Hoarding at platform	3.68	13.65	24.44	36.15	41.91	**750.82**	23%
2	Hoardings at Entry Area	0.35	1.29	2.32	3.43	3.98	**71.22**	2%

	Particular	2017	2021	2031	2041	2046	Total	Share
3	Glow Cubes	0.24	0.88	1.58	2.33	2.71	**48.46**	2%
4	Kiosks	0.01	0.05	0.08	0.12	0.14	**2.52**	0%
5	LED Displays	0.00	0.01	0.01	0.01	0.02	**0.28**	0%
6	Advertisements on Trains	0.78	4.83	12.22	22.10	27.71	**404.44**	13%
7	Advertisement on tickets	6.09	9.81	24.80	44.85	56.23	**829.98**	26%
8	Hoardings at Parking lots	0.64	2.38	4.26	6.30	7.30	**130.85**	4%
9	Advertisement on lifts	0.36	1.33	2.39	3.53	4.10	**73.38**	2%
10	Advertisements on escalators	0.13	0.49	0.88	1.30	1.50	**26.92**	1%
11	Ad on the pillars of elevated corridor	4.25	15.80	28.28	41.84	48.50	**868.82**	27%
	Total	**16.52**	**50.52**	**101.25**	**161.98**	**194.09**	**3207.71**	**100%**
B	**License Income**							
1	Tea And Refreshment Stalls	1.15	2.71	4.86	7.19	8.33	**149.90**	25%
2	ATMs	0.36	1.07	1.91	2.83	3.28	**58.94**	10%
3	Book Stalls	0.15	0.47	0.83	1.23	1.43	**25.58**	4%
4	Juice Stalls	0.40	0.94	1.68	2.49	2.89	**51.97**	8%
5	Milk And Milk Products Stalls	0.28	0.66	1.19	1.75	2.03	**36.57**	6%
6	Chemists	0.20	0.60	1.07	1.58	1.84	**32.98**	5%
7	Phone Booths	0.13	0.31	0.56	0.83	0.96	**17.41**	3%
8	Retail Kiosks	0.36	0.95	1.70	2.52	2.92	**52.47**	9%
9	Parking Lots	2.53	3.32	5.94	8.79	10.19	**185.96**	30%
	Total	**5.57**	**11.03**	**19.74**	**29.21**	**33.87**	**611.79**	100%

Source: Author's Estimates

The estimated revenue for RRTS from various sources is summarized below;

Table 4-22: Summary of estimated revenue

Particular (Rs. in Crore)	2017	2021	2031	2041	2046
Fare Box	995	1583	4090	9237	12801
Advertisement	17	51	101	162	194
License Fees	6	11	20	29	34
Carbon Credit	99	133	185	0	0
Net Revenue From TOD	794	2792	5412	0	0
Total	**1911**	**4570**	**9807**	**9428**	**13029**

Source: Author's Estimations

It can be seen that overall fare box collection contributes around 61% of the total revenue while TOD/property income is considered after deducting construction and administration cost for property development. It is around 36% of the total revenue. However the pattern of revenue stream in entire operation period is shown below:

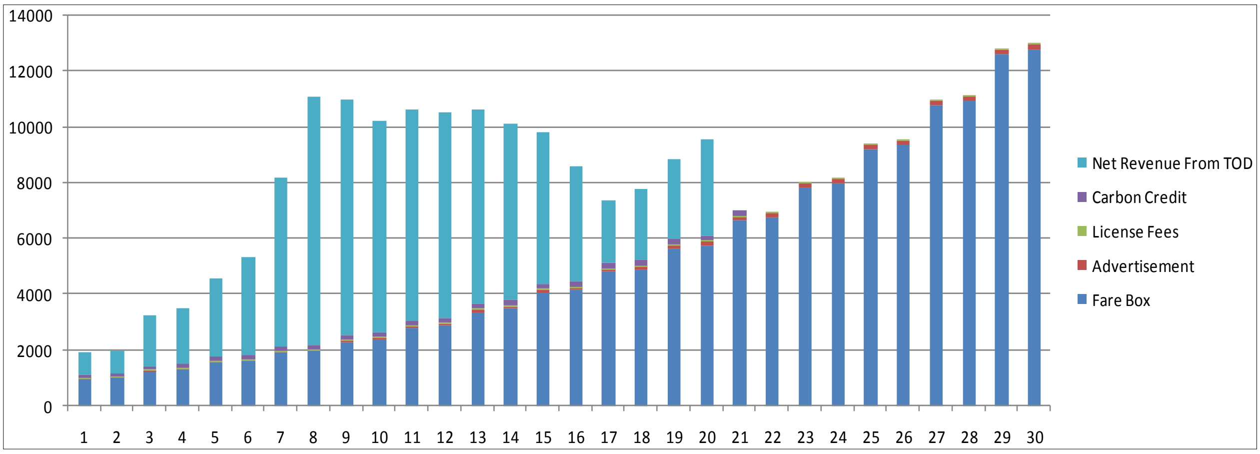


Figure 4-2: Pattern of revenue for RRTS

Revenue from property development is estimated to be the major source during middle years. Revenue from advertisement and licenses are envisaged to be trivial. The revenue from carbon credit is discussed in economic analysis in detail.

Other Assumptions

The assumptions related to taxation, depreciation and amortization prescribed as per Company's Act 1956 and Income Tax Act, 1961 are as follows;

Table 4-23: Depreciation and Tax related Assumptions

Depreciable components	Dep. Rates As per Income Tax Act	Dep. Rates As per Companies Act
E & M Works	60%	7.07%
Traction and Power		
Signaling and Telecom		
Rolling Stock (BG)		
Utilities		
Special noise & vibration reduction treatment equipments		
Alignment and Formation	10%	1.63%
Important Bridges		
Station Buildings		
Depot		

Depreciable components	Dep. Rates As per Income Tax Act	Dep. Rates As per Companies Act
Permanent Way		
CISF Barracks		
Amortization		
General Charges (Years)	5	
Income Tax Input		
Number of years for which 80IA benefit is available	10	
80 IA block of years	20	
Exemption Allowed u/s 80IA	100%	
MAT tax rate	19.35%	
Corporate Tax Rate	33.99%	
Cut off rate of Payable tax of the Book profit to introduce MAT	18.00%	

The corporate tax calculated in the financial model comprises of effects of Minimum Alternative Tax (MAT) as well as benefit available under IT Act. As per Income tax Act, u/s 80 IA, 100% income tax payable is exempted to infrastructure projects for a continuous period of 10 years during a block of 20 years. However during the exemption period, MAT is payable.

Based on the above estimations and inputs, a detailed financial model has been created to assess operational sustainability of RRTS and financial returns from the project in totality without considering the implementation model and agency. Operational Viability is discussed next.

4.6. Operational Viability of RRTS project

Operational Viability for the RRTS is described as follows:

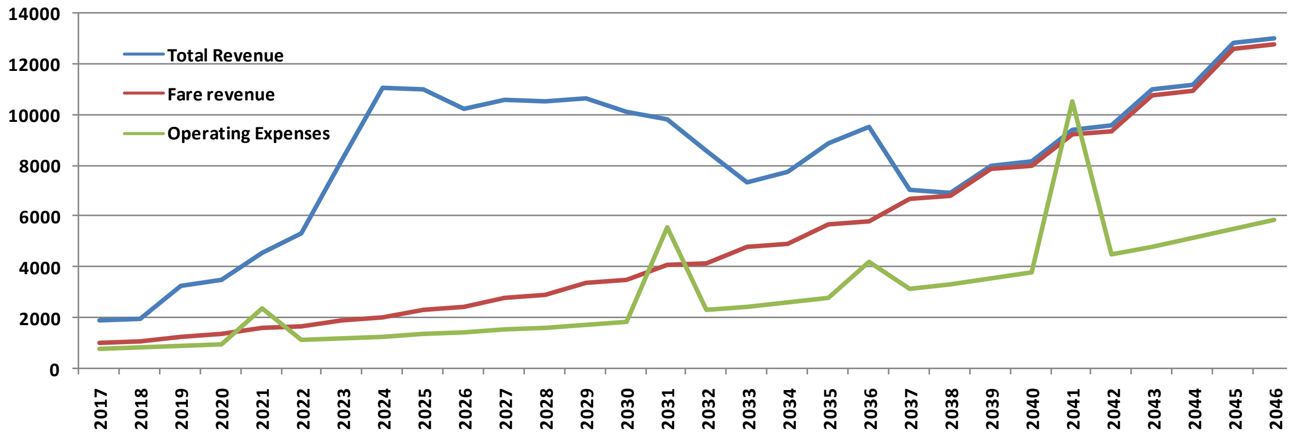


Figure 4-3: Operational viability of the project

It can be seen that the fare income is able to cover the operating expenses and the project is operationally viable even based on fare income alone. However fare revenues are not sufficient to allow recovery of investments in the project and debt service. For this purpose, property development is required.

Overall, the operating surplus is estimated to remain around more than 64% over the projection period. It is mainly due to Fare box revenues being supported handsomely by property development income. The fare revenue grows at 9% over 30 years (a combined effect of increase in fares and increase in traffic). Property revenues grow at 8% pa for 20 years. In comparison, there is a 7% pa growth on an average in O&M expenses over 30 years. The operating ratio decreases during periodic replacement of assets though.

4.7. Financial returns

The financial returns are calculated in terms of Internal Rate of Return (IRR) to assess the viability of the project. These returns are calculated without considering the financing options and implementation model which is done subsequently[4]. The projection of cash flow for the project is as follows:

[4] It is possible to calculate the IRR of an project cashflow without considering the financing options since interest costs are usually excluded from free cash flow in order to provide an opportunity to compare the returns with the cost of capital later.

Table 4-24: Projected cash flow for the Base Case

Particular	2012	2013	2014	2015	2016	2017	2021	2031	2041	2046
Rs. Crore										
Outflows										
Project Investments	2838	6016	9565	10139	3583					
O&M Costs						794	2376	5573	10558	5911
Taxes						0	0	1306	0	2392
Total Outflows (A)	**2838**	**6016**	**9565**	**10139**	**3583**	**794**	**2376**	**6879**	**10558**	**8303**
Inflows										
Revenue						1911	4570	9807	9428	13029
Total Inflows (B)	0	0	0	0	0	1911	4570	9807	9428	13029
Net Cashflow (B-A)	**(-) 2838**	**(-) 6016**	**(-) 9565**	**(-) 10139**	**(-) 3583**	**1117**	**2195**	**2928**	**(-) 1130**	**4726**
Project IRR	**10.55%**									

Source: Author's analysis

It is to be noted that if the project is developed by the Government SPV the Weighted Average Cost of Capital (WACC) would be around 5% due to access to soft loans from the multilaterals at low interest rates to the Government agencies. In this case the project is financially viable. However WACC in case of private sector could be as high as 12%-15% in which case the project becomes unviable. The above return can reduce nominally with inclusion of Interest During Construction (IDC) in the project cost.

Paucity of budgetary allocation and limited multilateral finance pose a big challenge to the government in terms of garnering the required resources for execution of such large scale project. However poor returns from mass transit projects keep the private away from participation. Under this situation project structuring becomes the crucial issue for successful implementation of the project. Various options for financing and project development have therefore been explored and are discussed further to arrive at suitable project financing and implementation structure.

4.8. Financing and Implementation models

Various Implementation models are analyzed for implementation of RRTS. The models are segregated in to three parts based on their respective nature as follows

1. Public Sector Models
2. Public Private Partnership (PPP) Models
3. Mix of public and private sector models (Revenue Share Model).

Involvement of public sector in project implementation would require equity contribution from Central and State Governments. Thus, various methods for interse allocation of equity among the State and Central Governments are explored before discussing the models themselves. The equity for this project would be shared only among the state Governments of Delhi, Haryana and Rajasthan and not Uttar Pradesh since the latter is not among the beneficiary for this project line.

It is estimated that MOUD, Ministry of Railways and NCPRB together would bring 50% of the total equity. Interse allocation between these Govt Departments would be decided by the Govt. of India. The State Governments of Delhi, Haryana and Rajasthan would bring rest 50% of the total equity.

Interse allocation of the equity among the above State Governments can be derived based on following alternative methods:

1. Allocation based on Length
2. Allocation based on Investment

Following table shows proposed equity participation of each state government based on length/investment of RRTS project

Table 4-25: Equity participation based on length

Particular	Length of the corridor (Km)	% of Total Investment as proportion of equity for 50% contribution
Govt. of Delhi	32	8.89%
Govt. of Haryana	78	21.7%
Govt. of Rajasthan	70	19.4%
	180	**50%**

Source: Author's analysis

The average cost of underground length of the project is estimated at Rs 306cr/km and that for the elevated portion at Rs.93 Cr. / km. Proportion of equity of each state government based on investment is thus as follows;

Table 4-26: Equity participation based on Investment

Particular	Adopted for proportion of equity for 50% contribution
Govt. of Delhi	19.5%
Govt. of Haryana	17.5%
Govt. of Rajasthan	13.0%
Total	**50%**

Source: Author's analysis

Between both the methods the equity allocation as per investment appears to be more balanced. For further analysis thus the allocation of equity as per investment based method is used, though it does not affect the project returns.

The alternative financing and implementation models are discussed further.

Public Sector Model

The urban rail rapid transit projects are recent developments in India. Kolkata Metro is the oldest urban rail project, which is run by Indian Railways. The Delhi Metro is the most successful example in the recent past. It is owned and operated by Delhi Metro Rail Corporation (DMRC), a SPV floated by GNCTD and GOI. Notably both the above projects are implemented and operated by Central and State Government agencies. The proposed Chennai and Bangalore Metro projects would be implemented based on DMRC model. Following is the funding pattern of Metro projects which are implemented and run by Public sector SPVs.

Table 4-27: Metro rail projects in India run by Public Sector agencies

Project	Length (Km)	Status	Total Project Cost *Rs. Crore*	Govt. Equity	Multilateral Debt	Other Sources
Kolkata Metro (N-S Corridor)	16.5	Operational	NA			
Kolkata Metro (Extension of N-S corridor)	8.7	Operational	NA	100%	Nil	Nil

Project	Length (Km)	Status	Total Project Cost *Rs. Crore*	Govt. Equity	Multilateral Debt	Other Sources
Kolkata Metro (E-W corridor)	13.74	Under Implementation	4676	55%	45% (JICA-ODA)	Nil
Delhi Metro (Phase 1)	65.1	Operational	NA	30%	60% (JICA-ODA)	10% Sub debt by GOI
Delhi Metro (Phase 2)	82.11	Operational		44% (Equity capital, Internal Accruals, Property Development)	46% (JICA-ODA)	10% Sub debt by GOI
Chennai Metro	45	Under Implementation	14600	30% (15% GOI and GOTN each	59% (JICA-ODA)	11% Sub debt by GOI and GOTN
Bangalore Metro	41.7	Under Implementation	8156	30% (15% GOI and GOKN each	45% (JICA-ODA)	25% Sub debt by GOI and GOKN

Source: DMRC DPR, other published sources
NA: Not Available

Public Sector Model under this report would imply implementation by SPVs owned by Central and State Governments. The SPV would develop, operate and maintain the RRTS project. It would also construct and sale the commercial residential properties at RRTS stations as discussed in TOD. The base project cost of Rs. 24600 crore would be escalated upto Rs. 32664 crore including the IDC.

Funding under this model is normally availed at concessional rates from the multilateral agencies. Maximum funding by Multilaterals (Mainly JICA) in other urban rail projects by Govt. entities has been observed at 60%. Considering the situation for this project, a situation can arise where debt is not available beyond 50% of project cost so as taken upto 45%. Equity contribution would remain 30%. Balance of the fund could be mobilized through 1) Creation of Mass Rapid Transit Fund (MRTF) and 2) Issue of tax free bonds 3) Cess on Stamp duty in TOD area 4) Interest free subordinate debt from State and Central Governments towards tax on project goods and cost of land. Following are the means of finance under this model.

Table 4-28: Means of finance for public sector model

Sr. No.	Means of Finance	Contribution	Rs. Crore
1	**Equity Contribution**	**30%**	**9799**
	Contribution of from GOI (MOUD, MOR and NCPRB)	*50%*	*4900*
	GNCT –Delhi	*19.5%*	*1911*
	Govt. of Haryana	*17.5%*	*1715*
	Govt. of Rajasthan	*13.0%*	*1274*
2	**Contribution from MRTF**	**5%**	**1633**
3	**Contribution from Cess on Stamp duty in TOD area**	**2%**	**728**
4	**Tax free bonds**	**5%**	**1633**
	Interest rate	8%	
	Bullet Repayment period (years)	5	
5	**Senior Debt**	**45%**	**14678**
	Term loan from Multi Laterals		
	Interest Rate pa	1.90%	
	Repayment Tenure (years)	30	
	Grace Period (years)	5	
	Effective Period (Years)	35	
6	**Subordinate Debt (Interest Free Loan) from Central Govt. for tax on project goods**	**8%**	**2611**
	Repayment Tenure (without grace period) (years)	10	
7	**Subordinate Debt (Interest Free Loan) from Central Govt. for cost of land acquired for the project**	**5%**	**1581**
	Repayment Tenure (without grace period) (years)	10	
	Total		**32664**

Source: Author's analysis

The interse allocation of the remaining 50% equity among the States is taken as discussed in the previous section.

Debt is proposed to be availed from multilaterals like JICA at a concessional rate of interest of 1.9%. The Interest Rate for multilateral is assumed to be a little higher than the standard 1.5% pa to account for Guarantee commissions and other costs charged by Central/State Governments. The proposed RRTS seems capable of sustaining this level of debt. The minimum DSCR works out to be 3.50. The average DSCR is 8.75. The hedging costs for the debt may work out to be in the range of 3-4% for yen dominated debt and are assumed to be borne by the Government.

The modalities of the proposed Mass Rapid Transit Fund, cess on stamp duty in TOD area and Tax free bonds are discussed further.

Mass Rapid Transit Fund (MRTF)

The proposed fund would be a revolving fund, dedicated to development and sustenance of Urban Mass Transit Systems in NCR and concerned States. The corpus of the fund can be collected from the following sources.

Table 4-29: Likely Sources for proposed MRTF

Sr. No.	Resources	Remarks
1	Cess on VAT	Applicable to entire state as the proposed RRTS would benefit entire state economy. As per estimations approx annual VAT collection of Delhi State was Rs. 11000 crore in 2009-10. While Rajasthan and Haryana have collected around Rs. 10000 crore and Rs. 9000 crore for the same period. The collection is estimated to grow at average 7% over next 30 years. By levying 0.5% cess on VAT, average Rs. 700 crore pa can be accumulated from the proposed fund.
2	Cess on Property Tax	Applicable to ULBs on RRTS corridor. Given the size and diversity, it is difficult to estimate the property tax. Implementation would be difficult due to opposition from fund starved small ULBs.
3	Cess on Building Use Permission	Applicable to the towns from which proposed project would pass. Difficulty of level for implementation would be same as Cess on property tax.
4	Sale of extra FSI	This is already captured in the development property under TOD and hence not considered here.
5	Cess on fuel /vehicle registration	Difficult to implement as the project area passes through jurisdictions of several states/cities. Not everyone in the affected states would be equally benefited from the project, and imposition in part of the state would be difficult to implement. It may be mentioned that GoKn has notified a law that allows collection of Rs 2 per litre on fuel purchased within Bangalore City.

Source: Author's estimations

Around 5% of the total project cost is proposed to be contributed from the above fund. The fund can be utilized for sustainability of the project operations.

Cess from Transactions

As discussed earlier, resource generation could be possible from other sources through application of statutory levies or cess. This cess could be levied upon those who are benefiting indirectly from the project. One such category of stakeholders is owners of property situated in the proximity to stations. These owners would benefit in terms of rise in prices of their property due to the project facility emerging in proximity. A financing mechanism for capturing part of this value arising to property owners could be structured as follows:

- Area approximating 1 sq km in radius around each station could be earmarked as the Delineated Area (DA). Property owners whose properties are situated in the DA would need to pay a cess on every transaction in addition to stamp duty and other statutory levies. Cess could be applied on transactions of both Built Up Area (BUA) and open area /plots situated in the DA. For this purpose cess of Rs 750/ sq mt for open area/plots and Rs 500/- per sq mt for BUA has been taken. Calculations are made only for BUA as transactions in land are difficult to estimate.
- A higher Floor Area Ratio (FAR) could be permitted in the Delineated Areas around stations situated away from urbanised areas based on concurrence of State Governments. Higher FAR of upto 3 could be permitted for this purpose. (Higher FAR may not be possible in stations situated in high density areas in and nearer New Delhi, except for specific TOD complexes constructed on the station box).

  Based on the above, estimates of income through the proposed TOD Cess on Transactions are calculated using the following inputs and assumptions:

Table 4-30: Estimation for delineated area for cess on transactions

No. of Stations	19
Radius (km)	1
Delineated Area near each station (sq km)	3.14
Delineated Area near each station (sq m)	3140000
Total del. area for all stations (sq. km)	60
Total del. area for all stations (hac.)	5966
Land Area already developed	30%
Land Area yet to be developed outside of urbanised areas	30%
Land Area already developed	1790
Land Area yet to be developed (hac)	1790
Remove 50% for green area/roads/common area (hac)	895
Net area for built up (hac)	895
Average FSI that will be consumed in DA outside urbanised areas	3
Total BUA (hac) - (A)	2685
Existing Developed land area (hac)	1790
Remove 65% for green areas, roads, common areas (hac)	1163
Net developed Land Area (hac)	626
Average FSI consumed	1.5
Total BUA (hac) - (F)	940

Source: Author's estimations

Following is the proposed rate for cess on transactions

Table 4-31: Proposed rate for Cess on Transactions

Rate for Cess on Transaction	(Rs/Sq mt)
Land Transaction	750
Property Transaction	500

Source: Author's estimations

Another key input to the calculations is the velocity of transactions (expressed as percent of total BUA in the Delineated Zone) whose ownership changes hands. The velocity is highest around the time the project is completed and then slows down to stabilise at a level of around 5% as shown below.

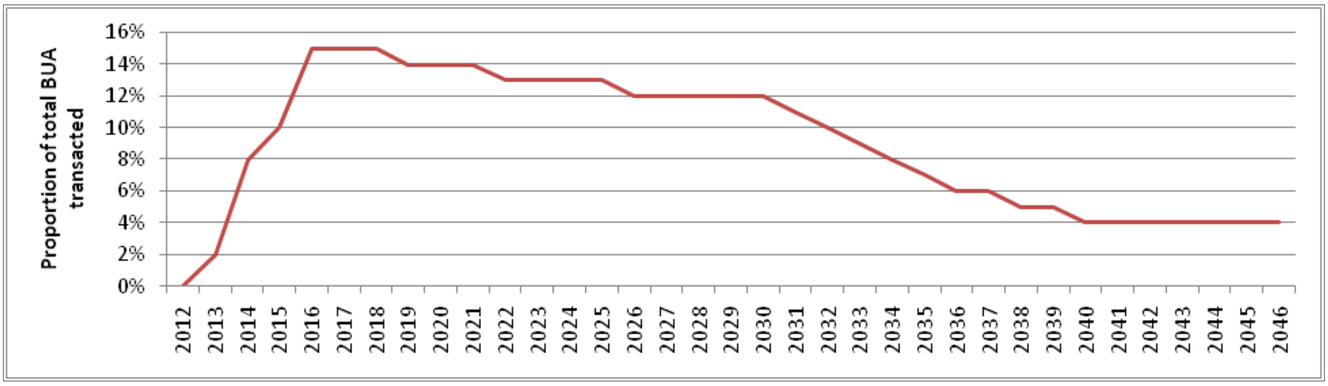


Figure 4-4: Velocity of transaction

Source: Author's estimations

It may be kept in mind that income will start during the construction years itself as soon as the transaction cess is levied. Using the above assumptions, the following income is estimated from TOD Cess.

Table 4-32: Calculation of Cess on transaction

Year	Cess Calculation for Area yet to be developed					Cess Calculation for Developed Area			
	Velocity of Transaction	Total BUA (hac)	BUA under transaction	Cess (Rs Crore)		Total BUA (hac)	BUA under transaction	Cess (Rs Crore)	Total Cess
	A	B	C = (A x B)	C x Rate		F	G = A x F	G x Rate	
2012	0%	2685	0	0		940	0	0	**0**
2013	2%	2685	54	27		940	19	9	**36**
2014	8%	2685	215	107		940	75	38	**145**
2015	10%	2685	268	134		940	94	47	**181**
2016	15%	2685	403	201		940	141	70	**272**
2017	15%	2685	403	201		940	141	70	**272**
2018	15%	2685	403	201		940	141	70	**272**
2019	14%	2685	376	188		940	132	66	**254**
2020	14%	2685	376	188		940	132	66	**254**
2021	14%	2685	376	188		940	132	66	**254**
2022	13%	2685	349	175		940	122	61	**236**
2023	13%	2685	349	175		940	122	61	**236**
2024	13%	2685	349	175		940	122	61	**236**
2025	13%	2685	349	175		940	122	61	**236**
2026	12%	2685	322	161		940	113	56	**217**
2027	12%	2685	322	161		940	113	56	**217**
2028	12%	2685	322	161		940	113	56	**217**

	Cess Calculation for Area yet to be developed					Cess Calculation for Developed Area			
Year	Velocity of Transaction	Total BUA (hac)	BUA under transaction	Cess (Rs Crore)		Total BUA (hac)	BUA under transaction	Cess (Rs Crore)	Total Cess
2029	12%	2685	322	161		940	113	56	**217**
2030	12%	2685	322	161		940	113	56	**217**
2031	11%	2685	295	148		940	103	52	**199**
2032	10%	2685	268	134		940	94	47	**181**
2033	9%	2685	242	121		940	85	42	**163**
2034	8%	2685	215	107		940	75	38	**145**
2035	7%	2685	188	94		940	66	33	**127**
2036	6%	2685	161	81		940	56	28	**109**
2037	6%	2685	161	81		940	56	28	**109**
2038	5%	2685	134	67		940	47	23	**91**
2039	5%	2685	134	67		940	47	23	**91**
2040	4%	2685	107	54		940	38	19	**72**
2041	4%	2685	107	54		940	38	19	**72**
2042	4%	2685	107	54		940	38	19	**72**
2043	4%	2685	107	54		940	38	19	**72**
2044	4%	2685	107	54		940	38	19	**72**
2045	4%	2685	107	54		940	38	19	**72**
2046	4%	2685	107	54		940	38	19	**72**

Source: Author's estimations

As can be seen, the total income from cess during construction years (2012-16) is Rs. 634 crore which can be used in the equity of the project. Further income during operations period (2017-2046) can flow to the project entity. **This income is considered to be accruing only to the Government project entity and not to any private sector partner and hence it has been considered only in the case of Public Sector Model and the Mixed Public and Private Sector Model and not in the case of PPP based implementation models.**

It must be mentioned that the above mechanism has the following limitations:

- Mechanisms will have to be worked out for cess collection and then transfer of this to the project entity. It is likely that collecting agency is revenue or local authority who are used to traditional manner of working. Hence integrating with them could be a challenge.

- Properties falling in the Delineated Area would have to be clearly identified and this information will have to be communicated to the Revenue or local authorities who would be collecting the cess. This could be cumbersome as this will require physical surveys to identify exact parcels which fall in the DA and outside.

In areas where property prices are low, the cess amount could represent up-to 3% of the property value. Paying this over and above the stamp duty and other levies could represent a very high cost for the property owners and therefore could dampen the property prices. However this is mitigated by the observation that property prices have tended to rise manifold in areas where such high quality public transit is introduced and this may well compensate the owners.

Tax free Bonds

In 2010, the GoI introduced a new section 80CCF in the Income Tax Act, 1961 to provide for tax deductions for subscribers to long-term infrastructure bonds and pursuant to that the Central Board of Direct Taxes passed Notification No. 48/2010/F.No.149/84/2010-SO(TPL) dated July 9, 2010. These long term infrastructure bonds offer an additional window of tax deduction of investments up to Rs. 20,000. This deduction is over and above the 1 lakh deduction available u/s 80C, 80CCC and 80CCD read with section 80CCE of the Income Tax Act. Infrastructure bonds help in intermediating the retail investor's savings into infrastructure sector directly. Such issuance provides a window to infrastructure projects for accessing cheaper funding as the interest rate (coupon) on these bonds could be fixed at a rate which is somewhat lower than the market rate for bonds of equal maturity.

In the RRTS project, the proposed public sector SPV can issue Bonds with above Tax Benefits to part finance the project cost. It would at current market rates for debt have to offer around 8% pa as the return to bond holders. It is envisaged that around 6% of the total project cost can be raised in this manner. Maturity period of bond could be 5 years and interest rate could be around 8%. The bonds would be repaid at one go (bullet) in the 5th year as the financial model shows that the project would have sufficient cash for repayment by that time.

Finally the subordinate debts are actually deferred payments to the Central and State Governments. Such debts are payable in first 10 years of operations.

Financial Returns

The Project IRR under this model is calculated to be 11.22%. As against this the WACC is 4.85% due to access to low cost funds. This means the project is financially viable under this model. The minimum DSCR of 3.50 and average DSCR of 8.75 also represents the adequate debt service capacity of the project.

Implementation models on Public Private Partnership basis are discussed further.

Public Private Partnership Models

As the experience of private participation in Infrastructure sectors like roads, ports, power generation etc. has been evolved and matured, it is replicated in urban infrastructure and transportation. As a result many upcoming metro projects are being implemented on PPP basis. Delhi Metro Airport Express link, Hyderabad Metro and Mumbai Metro are the fresh examples. However, structures of these PPP projects are different as showcased below:

Table 4-33: Metro rail projects in India implemented in PPP format

Projects	Concessionaire	Project cost *Rs. Crore*	VGF	Revenue Share (pa)	Means of Finance *Equity*	 *Debt*
Delhi Metro Airport Express Link *(Revenue Share Model)*	JV of Reliance Infrastructure Limited of India and Construcciones y Auxiliar De Ferrocarriles (CAF) of Spain	Total Project Cost = Rs. 5700 crore. Cost for the concessionaire: Rs. 2800 Crore[5]	Nil	Approx Rs. 51 Crore pa and 1% to 5% share in gross revenue[6]	30%	70%[7] 17.25 years Term loan by consortium of 8 banks lead by Axis bank

[5] DMRC Website
[6] World Bank PPI update note 39. September 2010
[7] World Bank PPI update note 39. September 2010

Projects	Concessionaire	Project cost	VGF	Revenue Share (pa)	Means of Finance	
		Rs. Crore			*Equity*	*Debt*
Hyderabad[8] Metro *(VGF Model)*	L&T Metro Rail (Hyderabad) Ltd.	16378	1458 (9% Total Project Cost)	Nil	21% (Rs. 3440 Crore)	70% (Rs. 11480 Crore)
Mumbai Metro - VAG Corridor *(VGF Model)*	Mumbai Metro One Pvt. Ltd. – Joint Venture of Reliance Energy Ltd and Veolia Transport of France	2356	650 (28% of the Total Project Cost)	Nil	22% (Rs.513 Crore)	50% (Rs. 1194 Crore)

Source: DMRC published information, World Bank data base, and Press release by concessionaires

As can be seen from the above, mainly two types of PPP models are implemented in rail based rapid transit systems in India. One is the Revenue Share model and the other is the VGF Model. In case of the Airport Express Line, concessionaire of this Delhi Airport Metro link project is responsible for all investments except civil works. The civil works have been carried out by DMRC. Thus the concessionaire is able to share revenue as the project investment is low.

In other cases VGF is required to make the project viable. The VGF share has ranged from 9% to 28%. The share of non fare revenue is expected to be fairly significant by the Concessionaire in case of the Hyderabad Metro.

Both Mumbai and Hyderabad projects are remarkable in the sense that they have been able to obtain debt on commercial terms for public transport projects which were hitherto considered non viable, even with some VGF. However, the debt servicing in the Hyderabad Metro is crucially dependent on the non fare income from property, and thus exposes the financiers to the risks of the property development business. Property development is notorious for its unpredictability and fluctuations, and the Reserve Bank of India has often limited Banks from taking exposure to this sector beyond a point through regulatory interventions. Thus, under the circumstances, the experience of Hyderabad Metro remains to be seen.

8 *Press release by L&T Metro Rail (Hyderabad) Limited on April 05,2011*

The financing for RRTS poses even greater challenges than the above project due to the size of the project cost. Further the quantum of property development involved is large, giving rise to huge uncertainties and risk. Thus newer models for implementation are required. Newer models may assist to reduce some risks through better allocation, though it cannot eliminate or even significantly reduce the risks.

Private Sector Models imply PPP models where full or partial projects are implemented by the private sector and the capital and operation expenditure is recovered either through rights to revenue streams or through annuity payments by the Government.

Possibilities of Private Sector Participation in the project are thus explored and the following PPP models are evaluated.

Table 4-34: Proposed PPP Models for the Project

Sr. No.	Format	Structure
1	VGF Model	Entire project cost to be borne by the private player. Land is acquired by the Government at its own cost (as proposed in Base Case), but rights are granted for Property Development/TOD to the concessionaire on this land. The concessionaire would ask for VGF in this case which would be the bidding variable. The overall share of VGF in the project cost would be capped at 40% as per Government policy in this regard which stipulates 20% funding by Govt. of India and 20% more from State Government / Sponsoring agency.
2	Annuity Model	An SPV would be formed for the project implementation by the Government. The private player would however bear the entire project cost. The revenue would be collected by the SPV. The concessionaire would ask for fixed annuity amount to be paid in equal annual installments over the entire concession period. The annuity amount would be the bidding variable.
3	Grant During Operation	The private player would bear 100% of project cost and collect the revenue as well. The Government would provide an equal amount of revenue shortfall grant every year for the entire concession period to maintain favorable returns of the concessionaire. The grant quoted per year would be the bidding variable.

Sr. No.	Format	Structure
4	Property Development by Private Sector	This model is a variation of the public sector model. Under this model, all activities other than property development continue to be undertaken by the Public Sector SPV. Since the real estate development would not be an area of expertise for the SPV (in base case scenario), the property development business can be concessioned to a private player. The private player would in return for these rights, pay upfront premium in installments during the initial years of operations. Total upfront premium (over a period) could be the bidding variable.

Source: Author's Analysis

The magnitude of the project cost and construction of huge amount of property are key challenges to private sector under various PPP formats. The private developer has to develop BUA of 56.73 Lakh Sq.mtr. The development of real estate is separate nature of business with it's own risk factors. The absence of expertise could jeopardize the revenue stream from the property development and further the financial viability of the project.

Multilateral assistance is not available for PPP projects. Thus the cost of debt would rise to 14%[9] (SBI PLR). Thus the project cost, owing to significant amount of Interest during Construction, would increase upto Rs. 36400 crore. It increases the risk of financial closure.

Each of the above option for PPP was analyzed and assessed. The outcome is presented below in tabular form.

Table 4-35: Assessment of PPP modes of Project Implementation Formats

Sr. No.	Formats	Assessment
1	VGF	• The Concessionaire would bear almost the entire project cost. However the land required for the project cost broadly at Rs. 2012 crore would be acquired by the Government and handed over to PPP partner for project and for TOD.

[9] *SBI PLR rate as on 13/08/2011 was 14.25%*

Sr. No.	Formats	Assessment
		• The Weighted Average Cost of Capital (WACC) [10] is 14%. • VGF level at 40% of Project Cost • PIRR is 15% and EIRR is 19%. Minimum DSCR is 0.87 Thus the project is barely viable under this model, given a difference of only 1% between cost of capital and PIRR. However it gives lower return than the cost of equity (20%). Also the project would not be able to service the debt. The returns would not attract the private sector. Also the private sector needs to be convinced of the high revenue potential from property development. However, the cap on VGF is 40% and hence the project fits within this policy.
2	Annuity	• The Concessionaire would bear 100% of the project cost • The annuity amount payable to the concessionaire by the Govt. would out to be around Rs.11000 crore pa to maintain Concessionaire PIRR of 18% while average annual revenue of the SPV is Rs. 8400 crore. • Annuity format in this case creates a profound long term liability on the Cash flow of the Government. • The Public sector SPV would end up paying Rs. 330000 crore as annuity amount over a period of 30 years against aggregate revenue of Rs. 25000 crore earned during the same period. Thus the SPV would require to pay an additional amount of Rs. 78000 crore over a period of 30 years. Therefore annuity would appear as an expensive option. Also the traffic risk is not passed on to the private sector.
3	Grant During Operation	• Entire project cost would be borne by the concessionaire. He would retain the project and property development revenue

[10] *WACC = (Sr.Debt (58%) * Cost of Debt (14%) + Subdebt (12%)*Cost of Debt (0%) +Equity (30%) * Cost of Equity (20%)*

Cost of equity is considered based on dividend paid by Listed companies over last few years.

Sr. No.	Formats	Assessment
		• The concessionaire would further ask for equal grant to be paid every year over the concession period of 30 years. The grant during operations works out to be Rs. 5300 crore annually to sustain the viability of the project for the concessionaire. This aggregates to 1.6 lakh crore over the concession period. Thus this works out to be an expensive option.
4	Property Development by Private Sector	• The concessionaire(s) would construct, market, lease and maintain the property. He would also retain the income from property. • The construction and lease rates as well as phasing are estimated to be the same as in the Base Case. • The concessionaire(s) would pay premium to the Public Sector SPV. 30% of the premium amount would be paid during the construction period (In 2016) while remaining part would be paid in seven equal installments during operation period. • The concessionaire(s) can pay Rs. 26000 crore as premium amount from property development over a period of 8 years between 2016-2023. In present value terms, this means that almost the entire project cost can be recovered through premium. • The key uncertainly and difficulty in this model is finding one or more private developers who are willing to purchase the rights to property development by payment of upfront premium. The actual premium that may be available might be lower since the private sector assumes the higher risk of delay in main project and also assumes the risk for off take of property. Also it may be difficult to identify all the land for property development for the Government in the beginning. Overall, it may not yield expected values as the property developers may see it as a huge unbundled risk.

Source: Author's Analysis

Mix of public and private sector model (Revenue Share Model):

We have earlier conceptualized and discussed pure public sector model for financing and implementation. We have also seen several options for PPP models. Finally a combination of public sector model and PPP model can be conceptualized through what could be termed as the Revenue Share Model. This model is somewhat akin to the implementation model for the Airport Express line of the Delhi Metro.

According to this model, the public sector SPV engages in land acquisition, civil construction, alignment and formation, R&R and some related items. This is financed through equity from Governments, MRT Fund, infrastructure Bonds, and multilateral (JICA) funding. The income from Cess on Transactions is also retained by the SPV.

A private sector Technology and Operations Company (Tech Ops) is retained by the SPV through competitive bidding. The Tech Ops Company is responsible for financing and construction of critical P-Way, all electrical, mechanical works, traction, power and rolling stock. The Tech Ops also operates and maintains the system besides collecting revenue such as fare, advertisement, license fee and TOD. Some part of the revenue is shared by the operator with the SPV which becomes the bidding criteria for selection of the operator company. The figure shown below illustrates this arrangement.

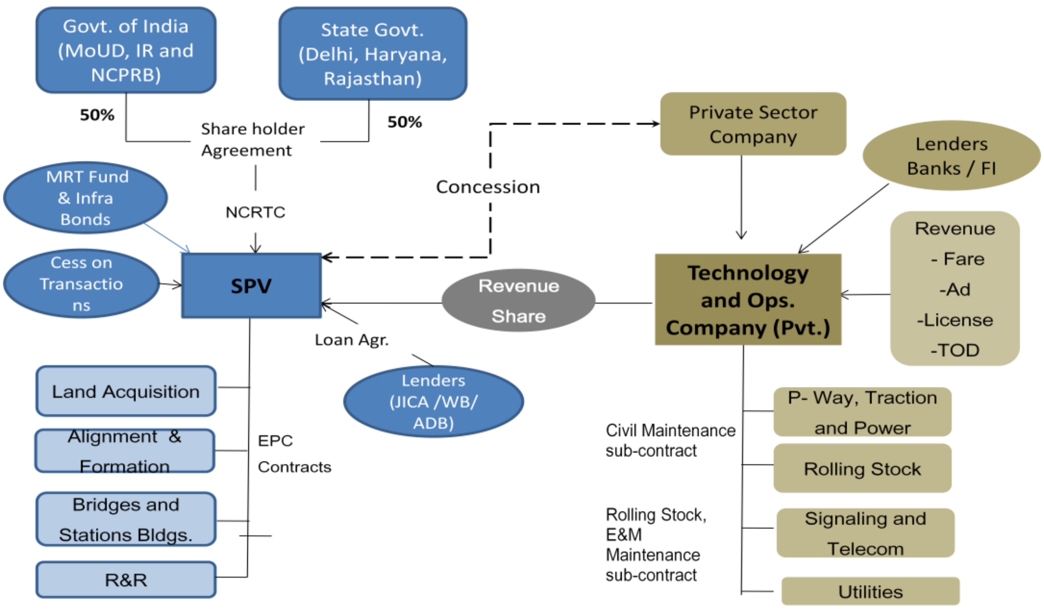


Figure 4-5: Structure of Revenue Share Model

Source: Author's Analysis

Accordingly the total project cost burden to the SPV and Tech Ops works out as follows:

Table 4-36: Project Cost for each Participant in the Revenue Share Model

Item	SPV	Tech Ops	Total
Govt Land	1317	0	1317
Pvt. Land	159	0	159
Alignment and Formation	10730	0	10730
Important Bridges	30	0	30
Station Buildings	1989	0	1989
E & M Works	0	659	659
Depot	0	200	200
Permanent Way	0	1245	1245
Traction and Power	0	846	846
Signalling and Telecom	0	1946	1946
Rolling Stock (BG)	0	3590	3590
Utilities	0	227	227
R&R	200	0	200
CISF Barracks	40	0	40
Special noise & vibration reduction treatment	0	50	50
General Charges including Design Charges	390	263	653
Contingencies	446	271	716
Total	15299	9297	**24596**
Share	62%	38%	100%

Source: Author's Analysis

The above arrangement gives the public sector the advantage of keeping the multilateral funding limited and keeping its cost of funding low. The TechOps will however be able to finance its share of the capital cost from equity and debt available on commercial terms. The overall funding pattern for the escalated project cost under this model would look like the following:

Table 4-37: Means of Finance for the Project under Revenue Share Model

Means of Finance	Contribution (%)	Project Cost (Rs. Crore)
SPV (Public Sector)		
Contribution of from GOI (MOUD, MOR and NCPRB)	15%	2989
GNCT -Delhi	6%	1166

Means of Finance	Contribution (%)	Project Cost (Rs. Crore)
Govt. of Haryana	5%	1046
Govt. of Rajasthan	4%	777
Cess on Property Transaction	4%	728
MRTF	5%	996
Bonds	5%	996
Soft loan	41%	8088
Sub Debt from Central and State Government for Tax	8%	1559
Sub Debt from State Government for Land	8%	1581
Total of above	**100%**	**19927**
Tech Ops Company (Private Sector)		
Equity Contribution	50%	6107
Senior Debt	41%	5055
Central and State Government for Tax	9%	1052
Total of above	**100%**	**12214**
Aggregate Total		**32141**

Source: Author's Analysis

Calculations show that the SPV is able to service its debt through receipts from Cess on Transactions and the Revenue Share it receives from TechOps. The Tech Ops is benefited through revenue from all sources including property development / TOD and hence is able to make a reasonable Equity IRR of 21% even after sharing a competitive 10% of the revenue.

4.9. Conclusion

On an escalated project cost of Rs. 32141 crore, the financial analysis for Alwar RRTS shows that the project is able to return an IRR of around 10%. This IRR is generic without considering financing options though such options are introduced subsequently in the chapter and discussed in detail.

The sources of revenue for the project are fares, advertisement and license incomes, and income from the proposed property development along stations (Transit Oriented Development). While the fares revenues are able to cover just the operational cost, higher project returns are possible due to income from property development. Income from property development is notoriously fickle and hence in order to keep the property development income conservative, a development period of 20 years for the TOD has been taken. This is in line with the fact that the project line runs into areas where industrial and urban development is only emerging and thus the demand for property will correspondingly have long gestation period.

Financing and implementation models are analyzed in this chapter next. Public Transit systems and particularly rail based systems are characterized by capital intensiveness and long gestation periods. This makes recovery of investment at a viable rate difficult, although the benefits to the economy and society are immense. Such systems generate externalities, which are not captured in the cash flow. (An attempt to capture both the costs and the benefits to the economy in the section on economic analysis next).

However subsidizing the capital and often even the operating costs is common for such systems around the World. Even Hong kong metro (MTR) which is considered to be a successful model for leverging through property development (37% income is from non fare sources) saw around 80% investment from the Government for the first three lines and around 66% for the next two lines.

However, the resource constraints with the exchequer and competing demand from other projects require that alternative funding models and mechanisms be examined. There is further a need to explore how the role of the private sector can be structured into the implementation so that private sector investment capacity, risk appetite and technology capability can be synergised with public sector to achieve project goals.

Keeping both the above in mind, innovative funding mechanism in terms of cess on property transactions has been discussed. The possible revenue through this mechanism has also been calculated and incorporated in some of the financing options discussed here. Further, several alternative financing models have been discussed here such as (i) public sector model (ii) PPP model and (iii) mix of public sector and private sector model.

The Public Sector Funding model primarily looks at the project as being implemented by the Public Sector SPV promoted by the Government of India and the State Governments. This model has the advantage of being able to attract cheap multilateral debt besides keeping public interest paramount. This model fixes the project cost at Rs.32664 crore after including both escalation and interest during Construction. The project IRR thus drops marginally to 10%. The chief disadvantage of this model is the difficulty associated with a Government SPV in playing the role of property developer. Property is one of key revenue streams and thus any delay or inefficiency in property development for TOD would result in lowering of returns. Thus this option has the prime disadvantage of exposing a public sector organisation to the (property market's) demand risk and which perhaps a public sector SPV may not be in the best position to negotiate. The analysis then looks at a few PPP models.

The final model discussed is the Revenue Share model. (Please see the section just before the conclusion). According to this model, the public sector SPV engages in land acquisition, civil construction, alignment and formation and some related items. A private sector operator is retained by the SPV which then is responsible for financing and construction of P-Way, all electrical, mechanical works, traction, power and rolling stock. The operator also operates and maintains the system besides collecting revenue. Some part of the revenue is shared by the operator with the SPV. This final model allows a balanced role for both the public and private sectors whereby the risk and returns seem to be allocated more judiciously in terms of their ability to bear. The model seems to have the following benefits:

i. It loads all technology related functions onto the private sector which is often more competent in this regard and hence could use its technological expertise in building and operating a modern system.
ii. It loads the revenue risk onto the private sector, in particular the demand risk from property development while allowing the SPV to share some of the revenue.
iii. It retains certain risks with the public sector such as Land Acquisition and R&R which are tasks best performed by the public sector.

iv. It allows the public sector to borrow cheap funds from a multilateral and hence this benefit is not lost for the project.

The limitation of the model seems to be its crucial dependence on the Cess on Transactions to get implemented since the SPV needs this source of funds in order to be able to repay the multilateral debt. On the upside, the cess on Transactions also raises the possibility of windfall profits to the SPV if the velocity of transactions rises higher than estimated.

The PPP models either appear unattractive for the private sector (VGF model) or are too expensive for the Government (Grant during Ops and Annuity models) or load a huge risk on the private sector making it unattractive for them and thus ability to get revenue from them uncertain (Property Development by Private Sector) Overall, the Revenue Share model and the Public Sector model both seem relatively better suited for implementation compared to others, though the Revenue Share model relies critically on the success of the Cess on Transactions and of the property development revenue to private operator company. The public sector model on the other hand loads all these risks are assumed on the public sector, perhaps as the only agency which could bear them given the magnitude.

The following table summarises the role of different parties and attractiveness in each financing and implementation model.

Table 4-38: Summary of implementation models through PPP

Model	Construction	O&M	Property Development	Attractiveness
Base Case	SPV	SPV	SPV	Higher
VGF	Pvt. Sector	Pvt. Sector	Pvt. Sector	Limited
Annuity	Pvt. Sector	Pvt. Sector	Pvt. Sector	Limited
Grant During Operations	Pvt. Sector	Pvt. Sector	Pvt. Sector	Limited
Only Property Dev.. By Pvt. Sec.	SPV	SPV	Pvt. Sector	Limited
Revenue Share	SPV and Pvt. Sector	Pvt. Sector	Pvt. Sector	Higher

Source: Author's Analysis

5. Economic Analysis

5.1. Executive Summary of Economic Analysis

The Economic analysis of RRTS project has been undertaken with an objective to evaluate the contribution of proposed RRTS project to social objectives and to the economy.

In order to assess economic viability, economic benefits and costs associated with the project have been identified to the extent possible. The "With project" scenario is compared with the option of "Without project scenario" to determine the economic benefits. The benefits consist of quantifiable and non quantifiable benefits. These are presented in table 5-1. The quantifiable benefits have been captured in this analysis.

Table 5-1: Summary of Quantifiable and Non Quantifiable Benefits.

Benefits	Quantifiable Benefits	Non Quantifiable Benefits
Fuel Savings	√	
Savings in capex of Vehicle	√	
Savings in Road Infrastructure Capex	√	
Savings in Road Infrastructure maintenance cost	√	
Savings due to pollution reduction	√	
Passenger Time Savings	√	
Savings in VoC	√	
Savings due to accidents reductions	√	
Econ. Impetus to micro region		√
Overall increased mobility		√
Better urban planning		√
Benefits to City Image		√
Better access to workplace due to TOD		√
Better Comfort Level to Passengers Traveling on RRTS		√
Indirect benefits of Reduce Pollution to Population leaving around project corridor		√

Source: Author Analysis

The total economic cost is subtracted from the total benefits to estimate the net benefit of the project. Discounted Cash Flow (DCF) technique has been used to determine the economic viability of the project. Detailed methodology and approach are described in subsequent section of Approach and Methodology section. The outcome of economic analysis is presented in table 5-2.

Table 5-2: Summary of Outcome of Economic Analysis

Particular	Outcome
Economic Internal Rate of Return	21.8%
Economic net present value (ENPV) @ 12% discount rate (Rs crore)	14667
Benefits to Cost ratio	1.76

Source: Author Analysis.

Further, the effects of increase/decrease of critical factors such as economic cost and benefits on economic viability of the project have been estimated through sensitivity tests. The result of the sensitivity tests for the project is presented in the table 5-3.

Table 5-3: Summary of Outcome of Sensitivity Analysis

Sensitivity parameters	EIRR	ENPV (Rs crore)	Benefits to Cost ratio
Increase in Economic Cost of the Project by 10%.	19.9%	12748	1.6
Decrease in benefits by 10%.	19.7%	11281	1.59
Combined scenario of increase in Economic Cost of the Project by 10% and decrease in Economic benefits by 10%.	17.9%	9363	1.44

Source: Author Analysis.

Based on the analysis following conclusions can be drawn.

- Project provides 21.8% of E-IRR which is higher than the social opportunity cost of capital i.e 12% normally used in the Asian context by ADB and World Bank. Thus on these counts, the returns are higher than the opportunity cost.
- Further the project provides 1.76 of benefits to cost ratio indicating 76% higher benefits would be accrued to the economy than the economic cost of the project.

- Project provides E-IRR of 17.9% under the most pessimistic scenario of increase in economic Cost of the Project by 10% *combined with* a decrease in economic benefits by 10% which is also determined to be higher than social cost of capital.
- Project also provides many quantifiable benefits which may further improve economic rate of returns.
- Thus project is determined to be economically viable.

The detailed discussion pertaining to economic costs and benefits are presented in the subsequent sections of the report. The discussion starts with the methodology for economic analysis followed by discussion on economic costs associated with the project and identification and quantification of benefits. Detailed output is presented in Annexure 5.

Final section discusses the economic viability of the project under the different sensitivity tests.

5.2. Approach and Methodology for Economic Analysis

The economic viability of the project has been carried out using the social cost benefit analysis approach and Discounted Cash Flow (DCF) technique. The financial project cost has been determined using the market prices. The economic project cost has been computed by applying appropriate conversion factor to the financial project cost. This has been done to remove distortion due to externalities and anomalies in market pricing system so as to arrive at the true cost to the economy. The detailed discussion pertaining to economic project cost is specified in economic cost section.

The project benefits have been computed through comparison of costs arising out of “with project” and “without project” scenario. For instance, in without project scenario, the economic costs incurred by the economy in carrying the diverted traffic to proposed RRTS project by the alternative mode of transport viz., road, rail has been computed. Therefore, the economic benefits would arise due to savings in cost that would accrue to the economy by moving the project traffic over the alternate mode of transport. In addition, other social benefits that would be accrue to the economy due to savings of direct/indirect costs namely, fuel savings, environmental pollution, accident reduction, maintenance cost, passenger time savings etc . These have been computed using the "with project" and "without project" scenario. These savings in social costs have also been considered to the extent that they are quantifiable. These social benefits have been computed based on economic prices instead of market prices. Shadow prices have been used to arrive at the economic costs/benefits. To arrive at the shadow prices, appropriate conversion factors (for converting market prices to economic cost) have been applied.

The pictorial representation of methodology of Economic analysis is specified in Figure 5-1 below.

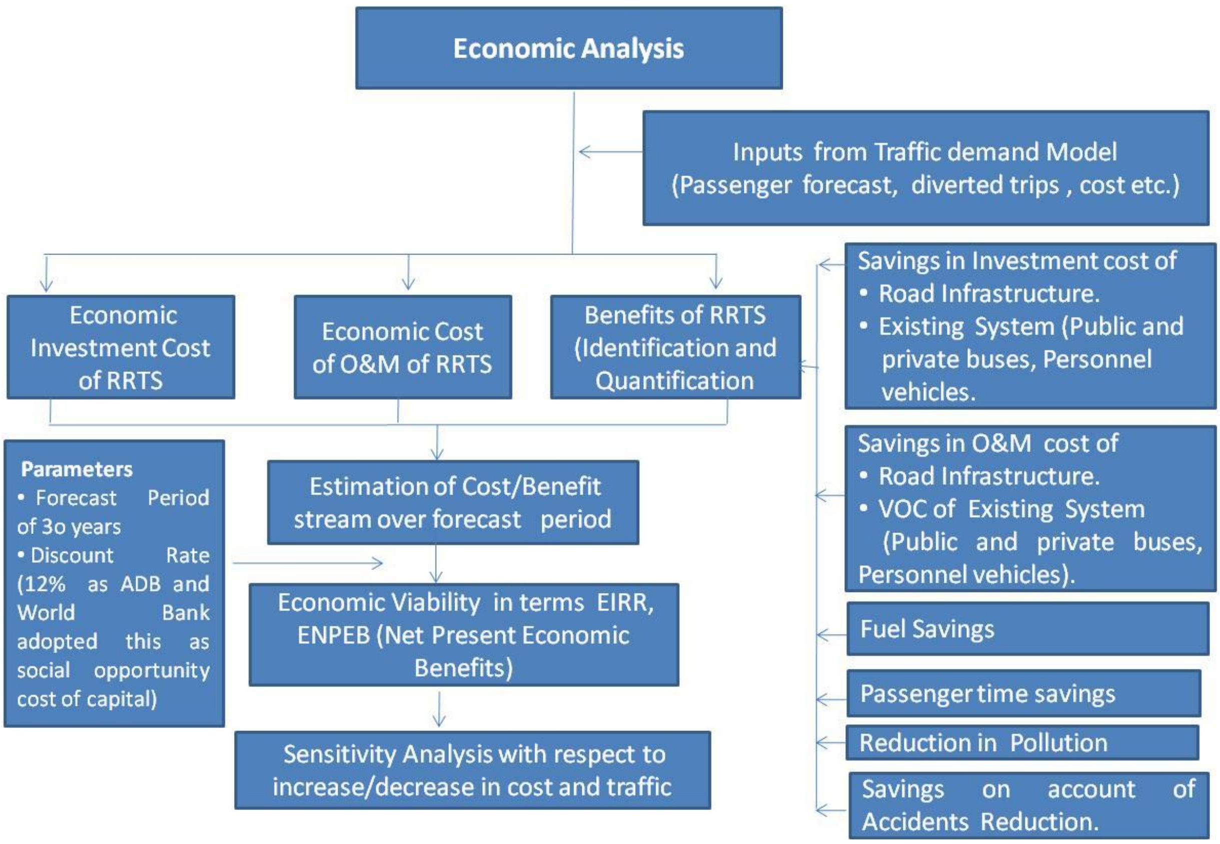


Figure 5-1: Methodology for Economic Analysis

Source: Author Analysis.

The annual stream of economic costs and benefits have been computed for analysis period of 30 years. Economic viability has been undertaken using the Discounted

Cash Flow (DCF) technique to obtain the economic internal rate of return (EIRR %) and economic net present value (ENPV) for the proposed project. This is followed by a 'sensitivity analysis' by increasing or decreasing the critical factors affecting the cost and benefit streams of the proposed project, in order to ascertain their effect on the economic feasibility indicators i.e. ENPV, EIRR.

5.3. Estimation of Economic Project Cost of RRTS

The Economic project cost (i.e. capital cost) of the RRTS is calculated from the financial project cost on the following basis.

- Tax components are excluded from the financial project cost as it represents transfer payments.
- Interest during Construction (IDC) has been excluded from the financial cost.
- On capital cost sides subsidies and market distortion including foreign exchange distortions are very difficult to evaluate. Therefore, the practice is to apply an overall conversion factor (CF) to cost figures to eliminate all possible distortions including foreign exchange distortions if applicable. ADB projects in the past have used in India a conversion factor (CF) equal to 0.90. Hence to eliminate all possible distortion owing to subsidies, wages of laborers and foreign exchange distortion, conversion factor equal to 0.9 have been used to arrive at Economic project cost.

The Economic project cost for the RRTS project is specified in table 5-4.

Table 5-4: Economic Cost of Project

Particular	Amount (Rs crore)
Land Cost (A)	1475
Total Hard Cost excluding Land Cost (B)	21751
General Charges including Design Charges @ 3% of B : (C)	653
Physical Contingencies @ 3% of (A+B+C) : (D)	716
Total Financial cost (A + B + C +D) (Excluding IDC and Taxes): (E)	**24596**
Economic Capital cost @ 0.9 of (E) above	**22136**

Source: Author Analysis

**Design charges include land layout design charges*

The construction period for the project is proposed as five years. The proposed phasing of construction is explained in the table 5-5.

Table 5-5: Phasing of Economic cost of Project

Year	Phasing	Economic Cost of Project (Rs crore)
2012	10%	2214
2013	20%	4427
2014	30%	6641
2015	30%	6641
2016	10%	2214
Total	**100%**	**22136**

Source: Author Analysis

As specified in above Table that total economic cost of the project is arrived at Rs 22136 crore at completion. Total net present value of Economic cost of project has been arrived at Rs 15709 crore using the discount rate of 12%.

5.4. Estimation of Economic cost of Operation and Maintenance

Operation and maintenance costs under "with the project" situation are derived from financial O&M estimates. As per the prevailing practice, only real prices has been considered in computation of economic O&M estimates. The conversion factor equal to 0.9 is applied to arrive at economic O&M estimates. This is owing to adjust the market prices for transfer payment like taxes, subsidies etc. for operation, repair& maintenance, material requirement and staff salary. The O&M Cost also includes replacement cost. Detailed discussion on financial O&M cost is specified in financial analysis chapter. Economic cost of Operation and Maintenance of RRTS project is summarized in table 5-6.

Table 5-6: Economic Cost of Operation & Maintenance

Particular	2017	2018	2019	2020	2021	2031	2036	2041
O&M Cost (in rs. Crore)	632	632	632	632	1330	1701	1895	1793

Source: Author Analysis

Total net present value of Economic cost of O&M has been arrived at Rs 3477 crore using the discount rate of 12%.

5.5. Economic Benefits of RRTS

As discussed, in the Approach and Methodology section, proposed project will accrue tangible and non tangible benefits due to reduction in traffic to existing system. It also contributes to diversion of passenger traffic from alternate mode i.e. Road and Rail to RRTS system. As a result there will be reduction in number of vehicles carrying passengers with introduction of RRTS and hence it also reduces congestion. This will also lead to savings in capex of transport system, i.e roads, rails, vehicles etc. In addition, other social benefits that would be accrue to the economy due to savings of direct/indirect costs namely, environmental pollution, accident reduction, maintenance cost, passenger time savings, vehicle operating cost etc. Following table 5-7 elaborates the quantifiable/non quantifiable benefit stream that would be accruing to economy with introduction of RRTS.

Table 5-7: Economic and Social Benefits arising from RRTS

<table>
<tr><th>Sr. No</th><th>Benefit</th><th>Direct Benefit due to RRTS</th><th>In direct benefits due to decongestion on other modes/routes owing to RRTS</th></tr>
<tr><td>1</td><td>Lower Capex in Vehicle i.e Bus, Car, Auto , Two wheelers ,Rail etc.</td><td rowspan="2">RRTS would significantly contribute in diversion of Traffic from existing mode of transport. This will lead to savings in followings.
• Capex of vehicles carrying the diverted trips.
• Capex of alternate mode of transport i.e Road that would be required to cater to increased traffic, in case RRTS is not introduced.</td><td></td></tr>
<tr><td>2</td><td>Lower capex of Existing mode of Transport i.e Road etc.</td><td></td></tr>
<tr><td>3</td><td>Reduced Road Stress</td><td>Reduced need for road maintenance due to reduced traffic on account of diverted trips on RRTS.</td><td></td></tr>
<tr><td>4</td><td>Lower Vehicle Operating Cost</td><td>Due to absence vehicles of diverted pax</td><td>Due to smoother operations of existing vehicles.</td></tr>
</table>

Sr. No	Benefit	Direct Benefit due to RRTS	In direct benefits due to decongestion on other modes/routes owing to RRTS
5	Fuel Saving	Fuel saved on vehicles of diverted pax.	Fuel saved by plying vehicles due to smoother operations on decongested roads.
6	Reduction in accidents	Lower accidents due to absence of vehicles of diverted pax	Lower accidents from plying vehicles due to decongested roads / other modes
7	Reduction in Pollution	Absence of carbon emissions from vehicles of diverted pax.	Lower emissions on decongested roads.
8	Passenger time saving	• Higher speed of RRTS as compared to present transport system . • Reduction of waiting time for people diverted to RRTS from existing Bus and Rail owing to higher frequency and speed.	Due to faster speeds possible from lower congestions levels, though this may also encourage car owners who would otherwise use public transport to use cars.
9	Better access to workplace due to TOD	Shorter trip distances for workers employed on TOD stations, employment etc.	
10	Econ. Impetus to micro region	Better and faster accessibility due to RRTS may enhance labour pool and skill availability with multiplier benefits	Improved accessibility due to decongested roads/other modes may enhance labour pool and skill availability with multiplier benefits.
11	Overall increased mobility	Better quality of life to citizens, particularly to daily commuters, women, students, elderly and disabled.	Benefits resulting from reduced congestion captured, other benefits may not be captured.
12	Better urban planning	Would make possible integrating land use with transport, enabling better town planning and contributing to efficiency due to better allocative efficiency of capital.	

Sr. No	Benefit	Direct Benefit due to RRTS	In direct benefits due to decongestion on other modes/routes owing to RRTS
13	Benefits to City Image	Would improve city image attracting higher investments and businesses, could decrease outmigration and increase immigration.	
14	Better Comfort Level to Passengers Traveling on RRTS	Improved quality of services, ease, reduction in crowding owing to higher frequency and speed. These factors enhance Comfort Level to Passengers.	
15	Indirect benefits of Reduce Pollution to Population leaving around project corridor	Diversion of Traffic will also contribute to reduced congestion and pollution thereof.	

Source: Author Analysis

- Impact can be quantified using proxies and estimates when necessary
- Impact difficult to quantified due to absence of universally accepted methods

Estimates of quantifiable benefits are explained in subsequent sections. While non quantifiable benefits have not been drawn in to analysis.

Transport Demand on RRTS

Existing Transport system on project corridor consist of Buses, Railway, shared auto rickshaw, cars and two wheelers. Traffic chapter provides details of the traffic demand estimates. The traffic demand estimates is in table 5-8.

Table 5-8: Traffic Demand on RRTS

Particular	2017	2021	2031	2041	2046
Total Peak hour Diverted Trips (Lakh)	0.74	0.91	1.26	1.51	1.68
Total Trips on RRTS (Lakh/ day)	7.37	9.12	12.55	15.11	16.27
Average Trip Length (km)	27.1	25.96	27.69	28.78	29.3

Source: Traffic Estimates and OD Analysis

Occupancy factors of different category of vehicles have been arrived based on actual traffic survey. These occupancy figures have been used to arrive at the numbers of diverted vehicles.

Table 5-9: Occupancy factors of different category of vehicles

Type of Vehicle	Occupation Factor/ Capacity Utilization
Two Wheelers	1.5
Car	2.25
Auto	5
Public Transport (BUS)	41.34
Rail	720[11]
Rolling stock (Engine+ wagon) per train	11

Source: Traffic Survey

Above occupancy factors and number of trips of each category of vehicle have been applied to total daily diverted trips to arrive at the daily diverted vehicles.

Table 5-10: Daily Diverted Vehicles *Figures in number*

Particular	2017	2021	2031	2041	2046
Two Wheelers	37982	52072	87384	98724	101941
Car	29653	43970	72528	77500	77828
Auto	2391	3350	3670	6658	8712
Public Transport (BUS)	1138	1186	1331	1587	1684
Rail	5	5	6	7	7
Total	**71169**	**100583**	**164918**	**184476**	**190172**

Source: Author Analysis

Based on Origin Destination analysis, average trip distance has been found out which has been specified in table 5-9. Annual vehicle run has been derived based on product of annual numbers of vehicle plying on the RRTS corridor, number of trips and average trip length.

Savings in Capital Cost of Vehicles

As specified above, with introduction of RRTS, there would be a reduction of vehicles such as Two wheelers, Cars, Auto, Buses, Rail etc on proposed corridor. As indicated in Table above, there would be a daily reduction of 71169 vehicles alone in 2017.

[11] Majority of long route trains are plying on this route and each train has 10 wagons with carrying capacity of 72 persons per wagon.

This reduction of vehicles corresponds to savings of capital expenditure. Further there would be a reduction of replacement cost of vehicles as each vehicle category has limited operational life. The operational life of Two wheelers, Car, Auto, Bus, Rail (Rolling stocks) have been considered 5 years, 12 years, 7 years, 10 years and 20 years respectively. This is based on prevailing industry practice.

In spite of efficient public transport system, there is a desire for owning a car and two wheelers among the people for weekends and for travelling outside the city. Thus it is assumed that only half of the diverted passengers (people diverted to RRTS and who would use the RRTS for commuting to work) would not be purchasing car and two wheelers.

Following estimates have been undertaken to arrive at savings in capex of different category of vehicles.

Table 5-11: Economic Price of Different Type of Vehicles

Particular	Financial Price of Vehicle at 2011 prices (Rs.)	Economic Price of Vehicle @ 0.9 of financial price at 2011 prices (Rs.)
Two Wheelers	50000	45000
Car	400000	360000
Auto	180000	162000
Public Transport (BUS)	2400000	2160000
Rail (Rolling stocks)	50000000	45000000

Source: Various sources and respective website of vehicle manufactures, Author Analysis.

Above mentioned economic prices of different vehicles have been used to arrive at savings in capex of vehicles which would have been diverted in “With RRTS Project” scenario. The savings with respect to diverted vehicles would be Rs 1169 crore in 2017 for the project. Year wise savings in capex of vehicles are specified in Annexure 5.

Total savings in economic cost of the vehicle during the 30 years operational years of RRTS would be Rs 6949 crore.

Savings in Road Infrastructure Cost and Land Acquisition Cost

The RRTS system would bring savings in investment in Road infrastructure. This is owing to shifting of passengers to RRTS system and reduction in vehicle in existing road infrastructure thereof. Owing to unavailability of information pertaining to existing capacity of road, it is assumed that diverted traffic would be accommodated in separate road corridor along the RRTS project corridor.

Indian Road Congress's norms for the PCU factors for various vehicle types have been used to arrive at peak hour PCUs of diverted traffic.

Peak hour Road capacity norms for level of service C, stipulated by Indian Road Congress (IRC) have been used to arrive at road infrastructure requirements. Based on this, it is worked out that total of three eight lane road, one six lane road and one four lane road would be required during operational years to accommodate the diverted traffic in "Without RRTS Project" scenario. While considering the prevailing road development plans and existing roads, it is worked out that two six lane roads and two four lane roads would be required during operational period of to accommodate the diverted traffic in "Without RRTS Project" scenario .Thus RRTS project would contribute in savings in road infrastructure investment in two six lane roads and two four lane roads.

Following road infrastructure cost norms have been used to arrive at Road infrastructure investment requirement.

Table 5-12: Norms used for Economic cost of Road Infrastructure

Capacity of Road	Financial Cost per KM (Rs crore) in 2011	Economic Cost per KM (Rs crore) in 2011 @0.9 of financial cost
4- lane	10.85	9.8
6-lane	14.7	13.22

Source: Planning Commission constituted B K Chaturvedi committee report for road infrastructure cost estimates[12].

Total savings in economic cost of the Road infrastructure during the 30 years of operational period would be Rs 2242 crore in present value terms. The discount rate of 12% is used to arrive at present value.

[12] B K Chaturvedi committee estimated road infrastructure cost of 4- lane and 6- lane road as Rs 9.6 crore per km and Rs 13 crore per km in 2009-10 respectively. While WPI of 6.31% is applied to derive the cost at 2011 prices.

Considering the prevailing norms, six lane highway and four lane highway requires 60 mt ROW and 45 mt ROW respectively. This translates into land area requirement of 1080 hac of land (180 km X 60 mt ROW) for six lane road and 810 hac of land (180 km X 45 mt ROW) for four lane road. Thus total land area requirement for construction of two six lane roads and two four lane roads is estimated at 3782 hac. It is considered that these roads would be constructed away from the proposed RRTS stations. Thus one third of the average prevailing circle late at proposed RRTS station is considered to arrive at savings in land acquisition. Total savings in economic cost of the land acquisition cost would be Rs 11353 crore in present value terms.

Savings in Road Infrastructure Maintenance Cost

As specified above, RRTS project would contribute in savings in road infrastructure investment in three eight lane roads and one four lane road. This will also lead to savings in road maintenance cost of these corridors which would have been occurred in "Without Project" scenario.

Prevailing industry norms for routine maintenance and periodic maintenance of Road infrastructure have been adopted in order to arrive at economic maintenance cost of Road infrastructure[13].

Total savings in economic Road infrastructure maintenance cost during the 30 years of operational period would be Rs 438 crore in present value terms.

Savings in Fuel Consumption

As a result of diversion of vehicular traffic to RRTS System, there would be a considerable savings in fuel consumptions. There would be an inter- fuel substitution of Petrol, Diesel and CNG to electricity. Fuel saved due to traffic diversion to RRTS is estimated using the following formula.

Savings in Fuel Consumption = (Annual Run of each Diverted Vehicle (i.e Vehicle Km)/ Fuel consumption Norms of different category of Vehicle i.e mileage) X Respective Fuel Prices.

[13] Annual Routine maintenance is adopted 1.5% of economic cost of road project. Periodic maintenance at 5% of economic project cost at regular interval of 5 years.

Using the above formula it is estimated that total cumulative savings in Petrol, Diesel and CNG are 30999 lakh lit., 13692 lakh lit., and 11399 lakh kg respectively during the thirty years of operational period. Fuel consumption norms used in analysis are stipulated below.

Table 5-13: Fuel Consumption Norms

Mode	Fuel Consumption Norms (Mileage)
Two wheelers (km/lit) (Petrol)	35
Car (km/lit) (Petrol)	13
Car (km/lit) (Diesel)	16.9
CNG Bus (km/KG)	2.94
Diesel (Km /Lit) for Bus	2.94
Auto Petrol (Km/Lit)	20
Auto CNG (Km/kG)	31.2
Consumption of Diesel per train km (Lit. per train km)	3.50

Source: Various sources, DTC, Industry estimates

It is also assumed that fuel of Auto and Bus shall be substituted by CNG form 2023 onwards. Prevailing fuel prices in Delhi as on 16th January, 2012 has been used to compute the savings in fuel consumptions.

Table 5-14: Fuel Prices

Type of Fuel	Price of Fuel
Petrol (Rs/lit)	68.26
Diesel (Rs/Lit)	46.2
CNG (Rs/KG)[14]	33.75

Source: IOCL, BPCL and Various sources. Note: Prices as on 16th January, 2012

Based on above, corresponding cumulative fuel savings would be Rs 3748 crore in net present value terms during the 30 years of operational period. Detailed year wise savings in fuel is presented in Annexure 5.

Savings due to Accident Reduction

The reduction in traffic volumes on road owing to modal transfer to RRTS System is expected to reduce the accidents on project corridor. Further reduction in accidents will also lead to savings from damaged to vehicle and savings towards medical and

[14] *Source: Average price In NCR Region as on 18 august, 2011.*

insurance expense to personal involved in the accidents. This also leads to reduction of productivity to the economy by the personal involved in the accident. Further it is to be noted that highest safety standards have been considered for RRTS project so as to minimal chance of accidents in RRTS system.

Owing to unavailability of past records of the accidents for vehicles plying in project corridor, The relationship exist between the number of vehicle playing and number of persons killed and injured in road accidents as specified in Road User Cost Study (CRRI, 1982) which is later updated by Dr. L.R. Kadiyali in association with Loss Prevention Association of India, have been considered[15] to measure the accident cost to the economy. This relationship is specified below.

1. **No of person Killed in Road Accidents:** Y1 = 49.43 *X + 750.42, Where: X= No of Vehicles affected in Lakh, Y1= number of persons killed in road accidents in a particular year, R square= 0.89.
2. **No of person injured in Road Accidents:** Y2 = 257.04 * X + 3181.41, Where: X= No of Vehicles affected in Lakh, Y2= number of persons injured in road accidents in a particular year, R square= 0.90.
3. **Damage of Vehicles :** Y = 143.63 * X + 3345, Where : X= No of Vehicles on the road , Y= damage to the vehicle in a particular year, R square= 0.90

Further to above past road accidents records stipulated by MORTH[16] have been assessed which displayed declining trends in road accidents and persons killed. The outcome of accidents estimated using the formula above is much higher than the accidents trends displayed by MORTH records. **Thus a very conservative approach has been undertaken by using the MORTH level of accidents estimates for future accidents in the "Without RRTS Project" scenario.**

Further to above, the Road User Cost Study also estimated cost of accidents which included components like gross loss of future output due to death/major injury, medical treatment expenses, legal expenses, and administrative expenses on police, insurance companies and the intangible psychosomatic cost of pain. The value of accidents and damaged to vehicle is presented in Table 5-15.

[15] *Source: Planning Commission constituted study "Social Cost Benefit Analysis of Delhi Metro" by Institute of Economic Growth by RITES*
[16] Ministry of Road Transport & Highway

Table 5-15: Economic Cost of Accident

Particular	Economic Cost (at 2011-12 Prices)
Cost of fatal accident (person killed) (Rs at 2011-12 prices)	437342
Cost of fatal accident (person Injured) (Rs at 2011-12 prices)	64256
Cost of damage to Two wheelers	2286
Cost of damage to Car	9763
Cost of damage to Bus	32818
Cost of damage to Auto	3900

Source: Planning Commission constituted study "Social Cost Benefit Analysis of Delhi Metro" by Institute of Economic Growth by RITES

Based on above, the reduction in accidents for different types of vehicles is estimated. The estimates of cost of damage to cars, buses and two-wheelers in road accidents, as reported in the above table are used to estimate the total savings in compensation paid due to damage caused vehicles. Thus total savings of Rs 2952 crore is estimated due to accident reduction in present value terms during the thirty years of operational period. Year wise details are presented in Annexure 5.

Savings due to Pollution Reduction

Factors such as fewer vehicles due to diversion to efficient RRTS System and decongesting existing road and rail network, would lead to reduction in green house gas emission in the region.

Unlike the existing transport system, which runs on a combination of petrol, diesel and CNG, the proposed RRTS Project will be operated entirely through electric system, thereby further enhancing the GHG emission reduction potential of the project.

Considering the above potential, United Nations Framework Convention for Climate Change (UNFCCC) approved methodology i.e "ACMOO16" for rail based MRTS have been used to estimate the possible carbon emission reduction. This methodology has been stipulated by UNFCCC under the possible financing through Clean Development Mechanism (CDM).

Based on above Methodology, Carbon finance i.e Monetization of emission reduction is calculated as follows.

Carbon Finance = Emission Reduction from RRTS Project x Price of per tone of CO_2.

Emission Reduction from Project: Baseline Emission (In without project, BAU) **-** Project Emission (Direct Project Emission + Indirect Project Emission).

The price of per tone of CO_2 is considered as Rs 800, which was carbon trading price in spot market in European Energy Exchange as on 12th August, 2011.

In order to estimate baseline emission, emission per kilometer run of each vehicle category has been estimated. Default vehicle technology improvement factor of 0.99 as stipulated under the UNFCCC methodology has been used to arrive at year wise emission factor of each vehicle category. Following emission parameters along with vehicle technology parameters has been used to estimate emission factor for each vehicle category.

Table 5-16 : Emission Parameters

Particular	Value	Unit
Net calorific value gasoline/Petrol	43.9	MJ/kg
Net calorific value diesel	42.7	MJ/kg
Net calorific value CNG	35.6	MJ/m3
Specific weight gasoline	0.759	kg/l
Specific weight diesel	0.83	kg/l
Specific weight CNG	0.717	kg/m3
CO_2 emission factor gasoline	67.5	gCO_2/MJ
CO_2 emission factor diesel	72.6	gCO_2/MJ
CO_2 emission factor CNG	54.3	gCO_2/MJ
CH_4 emission factor of CNG buses	162	gCO_2/km
CH_4 emission factor of CNG light vehicles	9.9	gCO_2/km

Source: BPCL and IPCC

Based on above inputs, emission parameters for each vehicle category and baseline emission in without project scenario has been estimated.

In order to estimates the saving in carbon emission, project emission (Emission due to RRTS Project) is estimated using the UNFCCC methodology. The methodology stipulated following formula for estimating the direct project emission.

PE y = EC pj, j,y X EF el, j,y X (1+ TDL j,y)

Where,

EC pj, j,y = Quantity of electricity consumed by the project electricity consumption source j in year y (MWh/yr).

EF el, j,y = Emission factor for electricity generation for source j in year y (tCO_2/ MWh).

TDL j,y = Average technical transmission and distribution losses for providing electricity to source j in year y

Following inputs have been plugged into above formula to estimate direct project emission.

Table 5-17: Emission Parameters for electricity grid

Particular	Value	Unit
Emission factor of Indian grid (EF el, j,y)*	0.81	tCO_2/MWh
Average technical transmission and distribution losses for providing electricity (TDL j,y)**	3.91%	Percent

*Source: *Emission factor of National Grid by Central Electricity Authority, ** Power Grid Corporation of India, 2010.*

Based on above, reduction in total emission is estimated at 64 million tones CO_2 during the operational period of 30 years.

Thus, pollution emission savings has been arrived at Rs 667 crore in net present value terms during the 30 years of operational period. Detailed year wise savings due to pollution reduction is presented in Annexure 5.

Passenger Time Savings

The RRTS system would be faster than alternate transport mode i.e road transport modes, existing rail etc. This will also lead to considerable saving in time of passenger travelling on RRTS System. The savings of travel time of passenger travelling by RRTS instead of alternate mode of transport is calculated as follows:

Passenger Time Savings = (Time spent by diverted Passenger on RRTS - Time spent by diverted passenger on alternate transport mode) X Value of Passenger

Average speed of two wheeler, car, shared auto, Bus and Existing railway is estimates at 25 km/hr, 40 km/hr, 15 km/hr, 35 km/hr and 50 km/hr respectively in the without project scenario. Speed of proposed RRTS is estimated at 90 km/hr, thus bringing enormous time saving benefits. Any benefits due to increase in speeds due to decongestion taking place on the roads in the “With Project Scenario” has not been considered in the analysis as we expect only a marginal rise in speeds and hence only very limited time savings.

The estimates for economic value of passenger time are stipulated below.

Table 5-18: Economic Value of Passenger Time[17]

Per	Amount (Rs per hour of Passenger) at 2011 prices
Value of Time of Passenger	94

Source: Author Estimates

With the implementation of the RRTS project, the total passenger time savings are estimated at Rs.9579 crore during the operational years in present value terms. Detailed year wise passenger time savings due to RRTS Project is presented in Annexure 5.

Savings in Waiting Time

Further it is also estimated that RRTS would bring benefits in terms of reduction of waiting of approximately 10 minutes for people diverted from existing Bus and Rail. Though the benefit accruing is meager and valued at Rs 6.6 crore during the operation period.

[17] *Daily average Income of passengers travelling on different vehicle category have been divided by daily working hours to arrive at value of passenger time.*

Savings in Vehicle Operating Cost

The reduction in vehicle operating cost (VoC) of diverted vehicle is obtained as product of annual run of diverted vehicle and VoC/ vehicle km.

Table 5-19: Vehicle Operating Cost Other than Fuel Cost

Vehicle Category	Voc/Km Other than Fuel Cost in 2011 (Rs)
Two wheelers	0.5
Car	1.25
Auto	1
Bus	15

Source: Industry norms and Author estimates

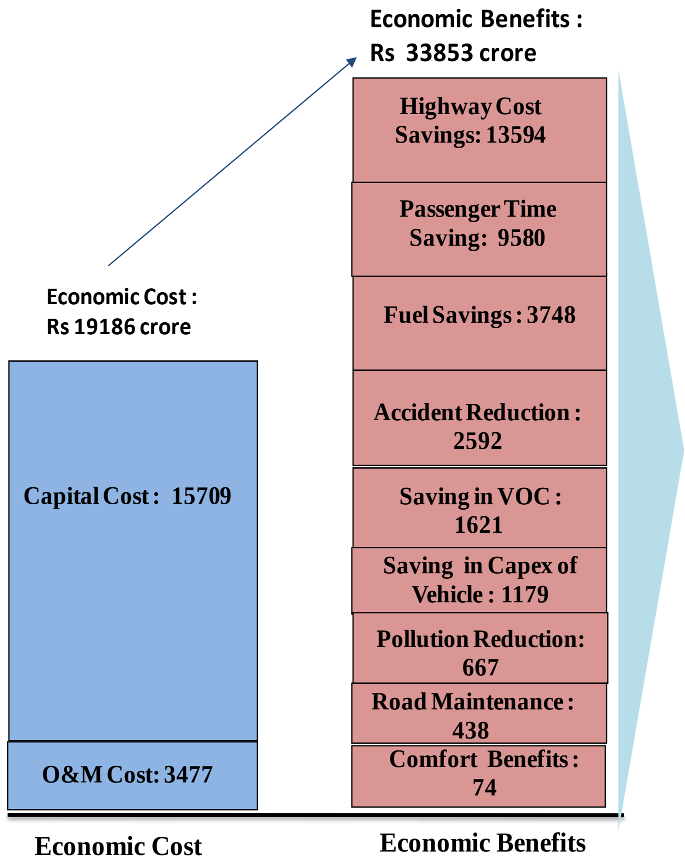
With the implementation of the RRTS project, the total savings in Vehicle Operating cost of diverted trips are estimated at Rs. 1621 crore during the operational years in present value terms. Year wise details are presented in Annexure 5.

5.6. Outcome on Economic Viability

The detailed discussion on outcome and sensitivity tests is specified below.

As discussed in section above, the cost and benefits streams for the thirty years period in economic prices have been estimated and presented in Annexure 5[18]. Further, the Discounted Cash Flow (DCF) technique has been used to obtain the economic internal rate of return (EIRR) and economic net present value (ENPV) for the RRTS Project. The result of the economic analysis is presented in table 5.20. The benefits are listed in the order of their magnitude, with the largest benefits accruing out of Highway Cost (about more than one third).

[18] It is to be noted that the residual value of the RRTS project in last year has not been taken into account as benefit.



Parameters	Outcome
Economic Internal Rate of Return	21.8%
Economic net present value (ENPV) @ 12% discount rate (Rs crore)	14667
Benefits to Cost ratio	1.76

Figure 5-2: Outcome of Economic Analysis (Amount in Present Value Terms)

Source: Author Analysis, Amount (Rs crore) in present value terms. (Graph not to scale)

As discussed above, in realistic/base traffic demand scenario, economic viability analysis is 21.8% EIRR which is higher than social cost of capital i.e 12%.

Above economic appraisal is based on estimates of project cost and benefits which indicates that economic viability of the project to a large extent depends on realization of these estimated benefits. Circumstances and situations which negate, or limit these economic benefits may reduce the economic viability. Similarly, situations of uncaptured benefits, or those that accelerate or enhance the value of captured benefits may further improve the economic rate of return.

To understand the impact of increase/decrease of critical factors such as economic cost, traffic and benefits on economic viability of the project to a certain extent, sensitivities tests with respect to followings have been carried out.

a) Increase in Economic Cost of the Project by 10%.
b) Decrease in benefits by 10%.

c) Combined scenario of increase in Economic Cost of the Project by 10% and decrease in Economic benefits by 10%.

The result is presented in Table 5-20 below.

The outcome of the economic viability under above mentioned sensitivity tests are presented in Table below.

Table 5-20: Economic Viability of Project under Different Sensitivity tests

Particular	Economic Internal Rate of Return @ 12% discount rate	Economic net present value (ENPV) @ 12% discount rate (Rs crore)	Benefits to Cost ratio
Increase in Economic Cost of the Project by 10%.	19.9%	12748	1.6
Decrease in benefits by 10%.	19.7%	11281	1.59
Combined scenario of increase in Economic Cost of the Project by 10% and decrease in Economic benefits by 10%.	17.9%	9363	1.44

Source: Author Analysis

It is seen from the above Table that under the different sensitivity tests, EIRR is more than 15% which is higher than the social cost of capital i.e 12%.

5.7. Conclusion

Following conclusion can be drawn from the economic analysis of the project.

- Project provides 21.8% of E-IRR which is higher than the social opportunity cost of capital i.e 12% normally used in the Asian context by ADB and World Bank. Thus on these counts, the returns are higher than the opportunity cost.
- Further it also provides 1.76 of benefits to cost ratio indicating 76% higher benefits would be accrued to the economy than the economic cost of the project if project is undertaken.
- Project provides E-IRR of 17.9% under the most pessimistic scenario of increase in economic Cost of the Project by 10% *combined with* a decrease in economic benefits by 10% which is also determined to be higher than social cost of capital.
- Project also provides many quantifiable benefits which may further improve economic rate of returns.
- Thus project is determined to be economically viable.

6. Assistance Required

6.1. Decision on the changes in alignment suggested by Haryana Government

The decisions regarding the change in alignment in Haryana area as suggested by Haryana Govt. officers and the related works involved are to be taken on priority. Our letters to NCRPB dated 22/12/11 and 26/12/11, copies at Annexure 2 may please be seen in this regard and go ahead given for the work to be carried out on the additional 35 kms (approximately) of new alignment in Haryana State.

6.2. Stakeholders Workshop

Field work of the Topographic survey and the Geotechnical investigations of the approved alignment have been completed. The alignment is being marked on the Revenue maps. The land for the line and land parcels for stations, parking and Transit Oriented Development (TOD) are being identified. On a preliminary assessment, the major issues for the consideration of stakeholders are availability of land and ROW for the RRTS, its Depots, Sub-stations, land parcels for TOD, identification of underground Utilities which would need to be diverted, and R & R issues. In our assessment the Stakeholders would include three State Governments, MORTH (NHAI), AAI, DLF, HSIDC, RIICO, Ministry of Railways, DMRC, DDA, MCD, NDMC, DTC, Electricity Authorities in the three States, and Land & Development Authority. NCRPB may please finalise the list of stakeholders for planning the workshop.

Thereafter, stakeholder workshop will be planned.

Annexure 1 : Minutes of CRC Meeting held on 14.10.2011

MD may like to Peruse.
03/01/11

राष्ट्रीय राजधानी क्षेत्र योजना बोर्ड
NATIONAL CAPITAL REGION PLANNING BOARD
प्रथम तल, कोर–IV बी/1st Floor, Core - IV B
भारत पर्यावास केन्द्र/India Habitat Centre
लोधी रोड, नई दिल्ली–110 003 / Lodhi Road, New Delhi-110 003
शहरी विकास मंत्रालय/Ministry of Urban Development
दूरभाष/Phone : 24642284, 24642287, फैक्स/Fax : 24642163

No.K-14011/59/2009-NCRPB (Vol.XI)

Dated: 01.11.11

Subject: Minutes of the meeting of Consultancy Review Committee (CRC)/Sub-committee to Task Force for the "Feasibility Study on Regional Rapid Transit System (RRTS) Corridors followed by Preparation of Detailed Project Report" for NCR held on 14.10.11

Meeting of Consultancy Review Committee (CRC) /Sub-committee to Task Force for the above mentioned study was held under the Chairmanship of Smt. Naini Jayaseelan, Member Secretary, NCR Planning Board on 14.10.11 at 03:00 P.M. Minutes of the same are enclosed for your kind perusal and necessary action.

Yours faithfully,

(R.C. Shukla)
Joint Director (T)

Encl.: As above

To,

1. Shri S.K. Lohia, OSD (UT) & EO JS, G. Floor, 'C' Wing, MoUD, Nirman Bhawan, New Delhi
2. Shri S.K. Singh, Joint Secretary (UT), Ministry of Urban Development, Nirman Bhawan, New Delhi
3. Shri P.K. Deb, Additional Chief Secretary, Urban Development, Local Self & Housing Department Govt. of Rajasthan, Room No.8223 New (221 Old), II Floor, S.S.O. Building, Secretariat, Jaipur- 302005
4. Shri S.S. Dhillon, Financial Commissioner & Principal Secretary, Town & Country Planning Deptt., Govt. of Haryana, Haryana Civil Secretariat, Sector 17, Chandigarh.
5. Shri R. Chandramohan, Pr. Secretary-cum-Commissioner (Tr.), GNCT-Delhi, 5/9, Under Hill Road, Delhi
6. Shri Ravindra Singh, Principal Secretary, Housing Department, Govt. of Uttar Pradesh, Bapu Bhawan, Vidhan Sabha Marg, Lucknow, Uttar Pradesh
7. Shri Bhuvnesh Kumar, Commissioner, Meerut Division, Govt. of UP, Civil Lines, Meerut, U P
8. Shri Rajiv Chaudhary, Executive Director (Works Planning), Railway Board, Ministry of Railways, Room no. 142-A, Rail Bhawan, New Delhi
9. Shri C.S. Verma, Additional Commissioner, NCR, Town & Country Planning Deptt., Navyug Market, Commercial Building, II Floor, Ghaziabad, U.P
10. Managing Director, Delhi Metro Rail Corporation Limited, Fire Brigade Lane, Barakhamba Road, New Delhi-110001
11. Shri Majid Ali, Principal Secretary, Transport; Transport Deptt., U.P. Secretariat, Lucknow, U.P.
12. Mrs. Keshni Anand Arora, Principal Secretary (Transport), Govt. of Haryana, Room No. 41, 7th Floor, Haryana Civil Secretariat, Sector 1, Chandigarh. Ph: 0172-2740278, Fax: 2700803
13. Shri Deepak Upreti, Pr. Secretary (Tr.), Govt. of Rajasthan, Parivahan Bhavan, Sahahkar Marg, Jaipur.
14. Shri S.K. Gupta, Chief Engineer (Planning), Delhi Metro Rail Corporation Limited, 7th Floor, Metro Bhawan, Fire Brigade Lane, Barakhamba Road, New Delhi-110001
15. Shri G.P. Garg, Advisor, Urban Mass Transit Company Ltd., 5th Floor, 'A' Wing, IFCI Tower, Nehru Place, New Delhi-110019

Copy to:
PS to Member Secretary, NCR Planning Board

Minutes of the Meeting of Consultancy Review Committee (CRC)/ Sub-Committee to Task Force for the "Feasibility Study on Regional Rapid Transit System (RRTS) Corridors followed by Preparation of Detailed Project Report" for National Capital Region held on 14.10.11 at 03:00 P.M.

Meeting of the Consultancy Review Committee (CRC)/ Sub-Committee to Task Force for the "Feasibility Study on Regional Rapid Transit System (RRTS) Corridors followed by Preparation of Detailed Project Report" for NCR was held under the Chairmanship of Smt. Naini Jayaseelan, Member Secretary, NCR Planning Board on 14.10.11 at 03:00 P.M. in the Conference Room of NIUA, II Floor, Core IV-B, India Habitat Centre, Lodhi Road, New Delhi. List of the participants is at **Appendix-I**.

2. Chairman welcomed the members of CRC & Consultants and requested them to make a detailed presentation on the Feasibility Report on Delhi-Gurgaon-Rewari-Alwar Corridor submitted by them on 27.09.11. Chairman also requested the representatives of State Governments to flag the issues related to their area, if any; during the meeting.

3. During the presentation, Shri S.S. Dhillon, Financial Commissioner & Principal Secretary (FC & PS), Town & Country Planning Deptt., Govt. of Haryana, suggested one more station between Rajiv Chowk and Manesar to be located near village Kherki-Daula where the NPR & SPR meet at NH-8. He also suggested that the land acquisition rates considered by Consultant are much less than prevalent rates in Haryana. Chairman suggested that land acquisition rates need to be increased as per the present scenario. Consultant was requested to interact with the State Governments for that.

4. Shri S.S. Dhillon also informed that the proposed alignment is in conflict to existing Master Plan in 3 towns viz. Dharuhera, Rewari and Bawal. In response to this, Consultant informed that the alignment considered by Govt. of Haryana is old; in the new/ approved alignment, there appears no conflict. Consultant was requested to incorporate suggestions of Govt. of Haryana and modified the alignment, if found conflicting with Master Plan.

5. Shri Dhillon also suggested that the FSI in TOD area should not be beyond 2.5, as Consultant has proposed 4. In response to this, Shri S.K. Lohia, OSD (UT), Ministry of Urban Development informed that the FAR in the TOD area are generally high to increase the financial viability of the Project as well as reduce the walking distance to access the public transport system along TOD. It also promotes linear development along public transport corridor. FSI in Bangluru and Mumbai TOD areas have been proposed as high as 4. In addition, Shri Subhash Chandra Sharma, DTP (NCR), Govt. of Rajasthan informed that unlimited FAR has been permitted along Jaipur Metro route, subject to provision of adequate parking. Shri Rajeev Malhotra, Chief Regional Planner, NCR Planning Board informed that high FAR is not proposed all along the corridor. It will be in TOD area only.

6. Shri S.K. Gupta, Chief Engineer Planning, DMRC made some suggestions. Most of the suggestions have been discussed earlier and decision was already taken in the earlier meetings. He opined that coach width should be 3.2 m wide, as no coach design for such speed for broad gauge is available. It will also increase size of tunnel structure, which lead to addition in construction and maintenance cost. The axle load should be limited to 17 tonnes. Beyond city limits, it was suggested that the corridor should be at-grade as evacuation problem at elevated tracks during accidents would be serious issue. It should have integration and common ticketing with DMRC. Delhi-Alwar corridor should go upto Rewari in 1st phase. Because, if the distance is more than 80 kms, toilet facilities in trains have to be provided.

9. Shri R.K. Karna, Director, NCR Planning Board informed that first the Debt:Equity ratio for the project should be decided, then equity distribution should be decided. It may be taken 30:70. The project should go as 'Pass-Through System' to avoid Government guarantee fee as 1.2%. Shri Lohia suggested that, Consultant can take DMRC funding system for RRTS also. He also pointed out that EIRR & FIRR needs revision.

10. Chairman suggested that we should avoid financing issues at this stage and concentrate more on technical issues

11. After discussions and deliberations following decisions were taken:

    i) Consultant should check the alignment at Dharuheda, Rewari and Bawal and modify, if found conflicting with Master Plan.

    ii) Land Cost taken for financial analysis need to be revised based on prevailing rates.

    iii) The amount due as Central Taxes would be treated as interest free subordinate debt to be shared between the Central and the State Government. The State Taxes shall be waived off/reimbursed by the States.

    iv) Contribution of project cost should not be taken as 12.5%. It is equity contribution just to form the company. It should be decided on the basis of length of RRTS corridor in the State and benefits thereon.

    v) Committee approved the Feasibility Report and directed to release the payment. The Committee directed to submit the addendum on Feasibility Report after incorporating the above suggestions.

Meeting ended with vote of thanks to the Chair.

Annexure 2 : UMTC Letters

Urban Mass Transit
Company Limited

No.UMTC/GPG/RRTS/NCRPB/144 Dated: 22.12.2011

To,

The Member Secretary
NCR Planning Board
Core IV-B, 1st Floor
India Habitat Centre, Lodhi Road
New Delhi – 110003

Sub: Consultancy Services for carrying out the feasibility study for Delhi-Gurgaon-Rewari-Alwar Regional Rapid Transit System (RRTS) corridor followed by preparation of Detailed Project Report (Contract No.3 of 2009-2010 dated 23.03.2010) – **Change of Alignment in Haryana.**

Ref:- Our letter No. UMTC/GPG/RRTS/NCRPB/127 Dated 15.11.2011

Madam,

During our presentation on "Feasibility Report" of Delhi - Alwar RRTS project to the Consultancy Review Committee (CRC) on 14.10.2011, Sh. S.S. Dhillon, Principal Secretary and Financial Commissioner, Town and Country Planning, Govt. of Haryana had raised the following points concerning the alignment.

1 One more station between Rajiv Chowk and Manesar be located near Village Kherki-Daula.
2 The proposed alignment is not in tune with the Master Plan in three towns viz Dharuhera, Rewari and Bawal, and will need modifications

The CRC had directed that the consultant should incorporate suggestions of Govt. of Haryana.

In accordance with the direction of CRC, we had detailed discussions with Senior Town Planner, Gurgaon and District Town Planner (DTP), Rewari on 09.11.2011, followed by the discussion with DTP, Rewari on 18.11.11 and finally in a meeting chaired by Sh. S.S. Dhillon at Chandigarh on 22.11.2011. After the discussion, we have marked the modifications in the alignment, required by Haryana Govt. in Dhruhera-Rewari-Bawal areas, on a Key Plan, and from rough measurement on a Google Map, the length of modification in the alignment works out to about 35 km, though the total length of the corridor will remain 180 km as before.

It is noteworthy that Delhi - Alwar RRTS alignment was finalised after field inspection and discussions with Haryana Govt. officers, and the same was presented in the Corridor Alignment Report submitted to NCRPB on 30.12.2010, which was approved by the CRC on 17.3.2011 and later on also by the Task Force on 29.06.2011.

Contd...2

Recd. 22/12/11

Registered Office : 5th Floor, 'A' Wing, IFCI Tower, 61 Nehru Place, New Delhi-110 019 t (91) 11 41606074/75/76/78 f (91) 11 26410763 | www.umtc.co.in

-2-

It is for your appreciation that the modification in the alignment now suggested by Haryana Govt. officers, involves fresh field visits, Topographic Survey and Geotechnical Investigation of about 35 km length and also an exercise on the traffic projections for the additional stations, which would require above 3 months time by the consultants to complete this job, and the consultant will have to incur additional expenditure on the manpower and the field investigations. The extra cost involved is being estimated and will be submitted shortly for your approval and go ahead.

A key plan showing the change in the alignment at Dharuhera and in Rewari-Bawal region, marked in red, is attached. Kindly advise us how we will be compensated for the extra work that will have to be done for the changed alignment in Haryana area and who will pay us for the same.

Assuring you our best services at all times.

Yours faithfully

(G. P. Garg)
Sr. Advisor

Encl: As Above

Urban Mass Transit
Company Limited

No.UMTC/GPG/RRTS/NCRPB/146 Dated : 26.12.2011

To,

The Member Secretary,
NCR Planning Board,
Core IV B, First Floor,
India Habitat Centre,
New Delhi – 110 003.

Sub: Consultancy Services for carrying out the feasibility study for Delhi-Gurgaon-Rewari-Alwar Regional Rapid Transit System (RRTS) corridor followed by preparation of Detailed Project Report – **Estimated Cost for additional work due to change of alignment in Haryana.**

Ref:- **Contract No.3 of 2009-2010 dated 23.03.2010.**

Madam,

This is in continuation of our letter No.UMTC/GPG/RRTS/NCRPB/144 dated 22.12.2011 on the above subject. The additional work required to be carried out due to modifications suggested by Haryana Govt. in the alignment will be as under:

1. Meetings with DTP, Rewari and field officials of HSIIDC as desired by Haryana Govt. in the minutes circulated by CCP (NCR), Panchkula, for finalising the amended alignment;
2. Reconnaissance of the area (about 35km in length) after setting the preliminary alignment on Google map;
3. Topographical Survey for 50 metres on either side of the additional length, and of wider land strips for locating Rewari station, the main maintenance depot near Rewari, as well as Kherki-Daula and Bawal stations;
4. Geo-technical investigations along the modified alignment and the depot area;
5. Designing the modified length of alignment and its plotting on the Topo Survey Sheets;
6. EIA and R&R issues in the modified alignment;
7. Exploring feasibility of TOD near the new sites of Kherki-Daula, Rewari and Bawal stations;

Contd..2

-2-

8. Revisiting travel demand forecasts by running traffic model due to change of stations;
9. Preparation of fresh Operation Plan/time tabling based on the revised traffic forecast and station distances;
10. Estimation of Project cost, Financial analysis and Economic analysis, after incorporating the changes;
11. Preparation of addendum to the Feasibility Report due to these large scale changes.

These activities will require about 3 months time over and above the present timelines. The cost of carrying out additional field investigations and that of the manpower required for above listed activities has been estimated to be Rs. 1.35 crores (Rs, One Crore and Thirty Five lakhs).

It is very kindly requested to please sanction additional Rs. 1.35 crores over and above the contract value, and convey your approval for taking up the above work at the earliest, so that we may remobilise our resources without any loss of time.

Assuring you our best services at all times.

Yours faithfully,

(G.P. Garg),
Senior Advisor

Annexure 3 : Advertisement space on each station

Sr. No.	Station Name	HOARDINGS PLATFORM AREA			HOARDINGS AT ENTRY POINTS			GLOW CUBES	KIOSKS	LED Displays (52 inches)	ADVERTISEMENT IN PARKING LOTS		ADVERTISEMENT ON LIFTS			
		Nos Left Hand Side	Nos. Right Hand Side	Area of hoarding (Per unit In sq. mt.)	Nos. of Hoardings (Left Hand Side)	Nos. of Hoardings (Right Hand Side)	Area of hoarding (Per unit In sq. mt.)	Nos.	Nos	Nos.	No. Hoardings	Size of unit (Sq.mtr)	Dimensions of one side of Lift (sq mt)	No. of Lifts	Dimensions of 5 sides of lift (sq mts)	Ad space out of total space (50% of total space)
1	Kashmere Gate	10	10	10.08	4	4	4.5	160	2	4	2	10.8	3.06	2	15.3	15.3
2	New Delhi	10	10	10.08	4	4	4.5	160	2	4	2	10.8	3.06	2	15.3	15.3
3	Nizamuddin	10	10	10.08	4	4	4.5	160	2	4	2	10.8	3.06	2	15.3	15.3
4	INA	10	10	10.08	4	4	4.5	160	2	4	2	10.8	3.06	2	15.3	15.3
5	Dhaula Kuan	10	10	10.08	4	4	4.5	160	2	4	2	10.8	3.06	2	15.3	15.3
6	Mahipalpur	10	10	10.08	4	4	4.5	160	2	4	2	10.8	3.06	2	15.3	15.3
7	Cyber city	10	10	4.5	4	4	4.5	128	2	4	2	10.8	3.06	2	15.3	15.3
8	IFFCO Chowk	10	10	4.5	4	4	4.5	128	2	4	2	10.8	3.06	2	15.3	15.3
9	Rajiv Chowk	10	10	4.5	4	4	4.5	128	2	4	2	10.8	3.06	2	15.3	15.3
10	Manesar	10	10	4.5	4	4	4.5	128	2	4	2	10.8	3.06	2	15.3	15.3
11	Panchgaon	10	10	4.5	4	4	4.5	128	2	4	2	10.8	3.06	2	15.3	15.3
12	Daruhera	10	10	4.5	4	4	4.5	128	2	4	2	10.8	3.06	2	15.3	15.3
13	BTK	10	10	4.5	4	4	4.5	128	2	4	2	10.8	3.06	2	15.3	15.3
14	MBIR	10	10	4.5	4	4	4.5	128	2	4	2	10.8	3.06	2	15.3	15.3
15	Rewari	10	10	4.5	4	4	4.5	128	2	4	2	10.8	3.06	2	15.3	15.3
16	Bawal	10	10	4.5	4	4	4.5	128	2	4	2	10.8	3.06	2	15.3	15.3
17	SNB	10	10	4.5	4	4	4.5	128	2	4	2	10.8	3.06	2	15.3	15.3
18	Khaital	10	10	4.5	4	4	4.5	128	2	4	2	10.8	3.06	2	15.3	15.3
19	Alwar	10	10	4.5	4	4	4.5	128	2	4	2	10.8	3.06	2	15.3	15.3

Annexure 4 : Projected Profit and Loss Account

Particular	2017 Rs. Crore	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2046
Fare Box	995	1049	1255	1324	1583	1635	1914	1976	2314	2389	2798	2889	3383	3492	4090	4166	4813	4903	5665	12801
Advertisement	17	26	37	44	51	55	59	64	69	75	80	85	90	95	101	108	114	121	127	194
License Fees	6	7	8	10	11	12	13	14	14	15	16	17	18	19	20	21	22	23	24	34
Carbon Credit	99	109	119	129	133	145	152	147	154	161	168	176	183	191	185	193	194	194	195	0
Net Revenue From TOD	794	779	1853	2005	2792	3521	6072	8895	8462	7594	7554	7358	6967	6336	5412	4131	2237	2529	2857	0
Total	**1911**	**1970**	**3272**	**3513**	**4570**	**5368**	**8210**	**11097**	**11014**	**10235**	**10616**	**10524**	**10641**	**10134**	**9807**	**8618**	**7380**	**7770**	**8869**	**13029**
Staff Salaries	220	240	262	285	311	339	370	403	439	479	522	569	620	676	737	803	875	954	1040	2683
Operations (Traction Expenses)	360	378	397	417	480	504	530	556	584	613	644	676	710	745	953	1000	1050	1103	1158	2074
Energy Expenses	162	172	182	193	205	217	230	244	258	274	290	308	326	346	366	388	412	436	462	878
Repair & Maintenance exp	51	54	57	61	64	68	72	77	81	86	91	97	103	109	115	122	130	137	146	276
Admin Expenses	0	0	0	0	1315	0	0	0	0	0	0	0	0	0	3402	0	0	0	0	0
Replacement in Equipment (10% of Project Cost)	220	240	262	285	311	339	370	403	439	479	522	569	620	676	737	803	875	954	1040	2683
Total	**794**	**844**	**898**	**956**	**2376**	**1128**	**1201**	**1279**	**1362**	**1452**	**1547**	**1649**	**1758**	**1875**	**5573**	**2314**	**2467**	**2630**	**2806**	**5911**
Operating Surplus (EBIDTA)	**1117**	**1126**	**2373**	**2557**	**2195**	**4239**	**7009**	**9817**	**9651**	**8783**	**9069**	**8875**	**8883**	**8259**	**4234**	**6304**	**4913**	**5139**	**6063**	**7118**
Operating surplus/Total Rev.	**58%**	**57%**	**73%**	**73%**	**48%**	**79%**	**85%**	**88%**	**88%**	**86%**	**85%**	**84%**	**83%**	**81%**	**43%**	**73%**	**67%**	**66%**	**68%**	**55%**
Depreciation (As per Cos Act)	900	900	900	900	900	900	900	900	900	900	900	900	900	900	368	279	279	279	279	279
Amortization	131	131	131	131	131	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PBT	**87**	**95**	**1343**	**1526**	**1165**	**3339**	**6109**	**8918**	**8752**	**7883**	**8170**	**7975**	**7983**	**7359**	**3866**	**6026**	**4635**	**4861**	**5784**	**6839**
TAX	0	0	0	0	0	0	0	0	0	0	0	0	2855	2660	1306	2023	1562	1650	1974	2392
PAT	**87**	**95**	**1343**	**1526**	**1165**	**3339**	**6109**	**8918**	**8752**	**7883**	**8170**	**7975**	**5128**	**4700**	**2560**	**4003**	**3072**	**3211**	**3811**	**4447**

Note: The above projections are for the generic model without taking into account the method of financing and implementation option. Thus interest cost in not considered.

Annexure 5 : Economic Cost and Benefit Streams for the Project

Amount in Rs Crore

Year	Economic Cost			Benefits											Net Benefits
	Capital Cost	O&M Cost	Total Cost	Fuel Savings	Savings in Capex of Vehicle	Savings due to accidents reductions	Savings in Highway Cost	Savings in Road Infrastructure maintenance cost	Savings due to pollution reduction	Passenger Time Savings	Savings in VoC	Savings due to Waiting time reduction	Comfort Benefits	Total Benefits	
2012	2214		2214	0	0	0	0	0	0	0	0	0	0		-2214
2013	4427		4427	0	0	0	0	0	0	0	0	0	0		-4427
2014	6641		6641	0	0	0	0	0	0	0	0	0	0		-6641
2015	6641		6641	0	0	0	0	0	0	0	0	0	0		-6641
2016	2214		2214	0	0	0	0	0	0	0	0	0	0		-2214
2017	0	632	632	562	1169	408	14409	36	99	1501	259	0.2	10	18453	17821
2018	0	632	632	600	73	443	0	36	109	1579	270	0.2	11	3121	2489
2019	0	632	632	641	78	481	0	36	119	1661	282	0.2	12	3310	2678
2020	0	632	632	684	83	522	0	36	129	1747	295	0.2	13	3509	2877
2021	0	1330	1330	729	89	566	14409	71	133	1837	308	0.2	14	18157	16827
2022	0	669	669	767	142	594	0	190	145	1905	321	0.2	14	4079	3410
2023	0	669	669	744	66	622	0	71	152	1975	335	0.2	15	3981	3312
2024	0	669	669	784	107	652	0	71	147	2049	349	0.2	16	4175	3506
2025	0	669	669	826	74	684	0	190	154	2124	363	0.2	17	4433	3764
2026	0	669	669	870	77	717	0	71	161	2203	378	0.2	18	4495	3827
2027	0	669	669	916	409	751	0	190	168	2285	394	0.2	19	5132	4463
2028	0	669	669	964	91	786	0	71	176	2370	411	0.2	20	4889	4220
2029	0	669	669	1015	624	823	0	71	183	2457	428	0.2	21	5623	4954
2030	0	669	669	1068	150	862	10779	217	191	2549	445	0.2	22	16283	15615
2031	0	1701	1701	1124	197	902	0	98	185	2643	464	0.2	23	5635	3934
2032	0	746	746	1142	201	915	0	217	193	2721	473	0.2	24	5885	5139

Year	Economic Cost			Benefits											Net Benefits
	Capital Cost	O&M Cost	Total Cost	Fuel Savings	Savings in Capex of Vehicle	Savings due to accidents reductions	Savings in Highway Cost	Savings in Road Infrastructure maintenance cost	Savings due to pollution reduction	Passenger Time Savings	Savings in VoC	Savings due to Waiting time reduction	Comfort Benefits	Total Benefit s	
2033	0	746	746	1161	129	928	0	98	194	2802	482	0.2	24	5817	5071
2034	0	746	746	1179	100	941	0	186	194	2886	491	0.2	24	6002	5256
2035	0	746	746	1198	103	954	0	217	195	2973	501	0.2	25	6165	5419
2036	0	1895	1895	1217	348	967	0	98	196	3063	510	0.2	25	6424	4530
2037	0	746	746	1236	450	981	0	217	196	3156	520	0.2	26	6781	6035
2038	0	746	746	1255	149	994	0	98	197	3253	530	0.2	26	6502	5755
2039	0	746	746	1274	119	1008	0	186	197	3353	540	0.2	27	6704	5957
2040	0	746	746	1293	122	1021	10779	243	198	3457	550	0.2	27	17692	16945
2041	0	1793	1793	1312	661	1035	0	124	188	3566	560	0.3	28	7473	5680
2042	0	801	801	1327	259	1045	0	243	188	3665	568	0.3	28	7323	6522
2043	0	801	801	1341	185	1055	0	124	187	3767	576	0.3	28	7265	6463
2044	0	801	801	1355	140	1065	0	212	187	3873	585	0.3	29	7446	6644
2045	0	801	801	1369	185	1075	0	331	186	3983	593	0.3	29	7751	6950
2046	0	801	801	1383	369	1085	0	243	185	4096	602	0.3	30	7993	7191

Annexure 6 : Km wise fares

Slab based flat fare						Distance based fare													
KM	**Fare (Rs.)**	**KM**	**Fare (Rs.)**	**KM**	**Fare (Rs.)**	**KM**	**Fare (Rs.)**	**KM**	**Fare (Rs.)**	**KM**	**Fare (Rs.)**	**KM**	**Fare (Rs.)**	**KM**	**Fare (Rs.)**	**KM**	**Fare (Rs.)**	**KM**	**Fare (Rs.)**
1	15	**11**	20	**21**	30	**31**	34	**41**	42	**51**	56	**61**	67	**71**	78	**81**	89
2	15	**12**	20	**22**	30	**32**	34	**42**	43	**52**	57	**62**	68	**72**	79	**82**	90
3	15	**13**	20	**23**	30	**33**	34	**43**	44	**53**	58	**63**	69	**73**	80	**83**	91
4	15	**14**	20	**24**	30	**34**	34	**44**	45	**54**	59	**64**	70	**74**	81	**84**	92
5	15	**15**	20	**25**	30	**35**	34	**45**	46	**55**	61	**65**	72	**75**	83	**85**	94
6	15	**16**	20	**26**	32	**36**	37	**46**	47	**56**	62	**66**	73	**76**	84	**86**	95
7	15	**17**	20	**27**	32	**37**	38	**47**	48	**57**	63	**67**	74	**77**	85	**87**	96
8	15	**18**	20	**28**	32	**38**	39	**48**	49	**58**	64	**68**	75	**78**	86	**88**	97
9	15	**19**	20	**29**	32	**39**	40	**49**	50	**59**	65	**69**	76	**79**	87	**89**	98
10	15	**20**	20	**30**	32	**40**	41	**50**	52	**60**	66	**70**	77	**80**	88	**90**	99

Distance based fare																			
KM	**Fare (Rs.)**	**KM**	**Fare (Rs.)**	**KM**	**Fare (Rs.)**	**KM**	**Fare (Rs.)**	**KM**	**Fare (Rs.)**	**KM**	**Fare (Rs.)**	**KM**	**Fare (Rs.)**	**KM**	**Fare (Rs.)**	**KM**	**Fare (Rs.)**	**KM**	**Fare (Rs.)**
91	100	**101**	111	**111**	122	**121**	133	**131**	144	**141**	155	**151**	166	**161**	177	**171**	188
92	101	**102**	112	**112**	123	**122**	134	**132**	145	**142**	156	**152**	167	**162**	178	**172**	189
93	102	**103**	113	**113**	124	**123**	135	**133**	146	**143**	157	**153**	168	**163**	179	**173**	190
94	103	**104**	114	**114**	125	**124**	136	**134**	147	**144**	158	**154**	169	**164**	180	**174**	191
95	105	**105**	116	**115**	127	**125**	138	**135**	149	**145**	160	**155**	171	**165**	182	**175**	193
96	106	**106**	117	**116**	128	**126**	139	**136**	150	**146**	161	**156**	172	**166**	183	**176**	194
97	107	**107**	118	**117**	129	**127**	140	**137**	151	**147**	162	**157**	173	**167**	184	**177**	195
98	108	**108**	119	**118**	130	**128**	141	**138**	152	**148**	163	**158**	174	**168**	185	**178**	196
99	109	**109**	120	**119**	131	**129**	142	**139**	153	**149**	164	159	175	**169**	186	**179**	197
100	110	**110**	121	**120**	132	**130**	143	**140**	154	**150**	165	**160**	176	**170**	187	**180**	198