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0. EXECUTIVE SUMMARY

0.1 Background

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

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

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

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

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

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

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

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

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

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

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

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

The proposed Regional Rapid Transit System (RRTS) corridor between Delhi, Sonepat and Panipat is envisaged as part of the National Capital Region Planning Board's Transport Mobility Plan 2021 for a Mass Rapid Transit System that could provide an effective, high-speed and world class solution to benefit ridership between the cities of Panipat, Sonepat and towns of Kundli, Rajeev Gandhi Educational University, Murthal, Samalkha and Ganaur with Delhi. The RRTS corridor has been proposed to create a cost-effective yet world class transportation solution to provide a much needed relief to the NCR commuters and to discourage congestion within Delhi, a city bursting at its seams with inflow of population and strained resources and infrastructure.

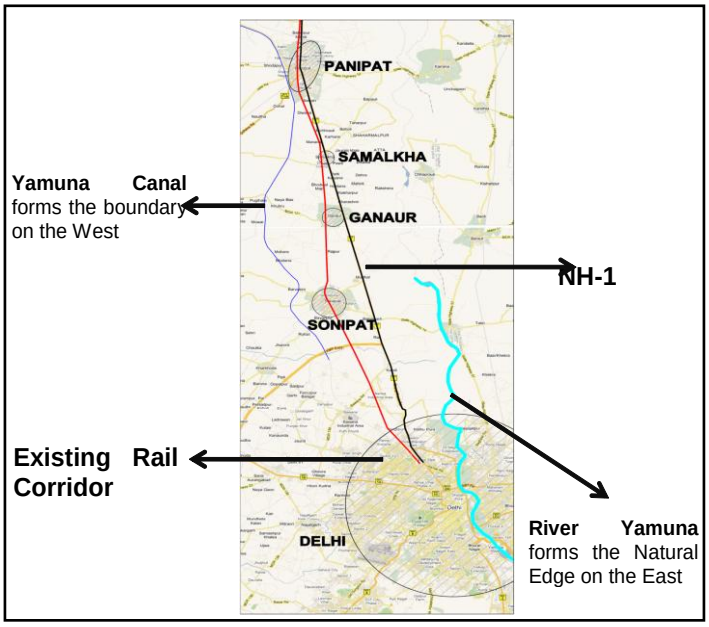
0.2 Agency

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

0.3 Vision of RRTS

The Delhi-Sonepat-Panipat project corridor is in the states of Haryana and Delhi. The cities of Delhi and Panipat are connected through NH1 (6/8 lane highway) and Indian Railways trunk line. The cities and towns that lie in between Delhi and Panipat served by NH1 and the Indian Railway trunk line are Sonepat Ganaur, Samalkha, Kundli and Rai. It has been observed that most of the settlements/ development in these cities has taken place between the NH1 and Indian Railway corridor that provide connectivity between these cities as well as connectivity with Delhi and Panipat.

The project corridor is bound by the River Yamuna on the eastern fringe and the Western Yamuna Canal on the western side. It is generally observed that there is not much population to the east of NH-1, and almost all the city centres in Haryana state are located to the west of NH-1 upto Ambala. The Yamuna River serves as the boundary between the states of Haryana and Uttar Pradesh. The western Yamuna Canal, NH-1 and the existing Indian Railway line are defined, continuous alignments between Delhi to Panipat and beyond.

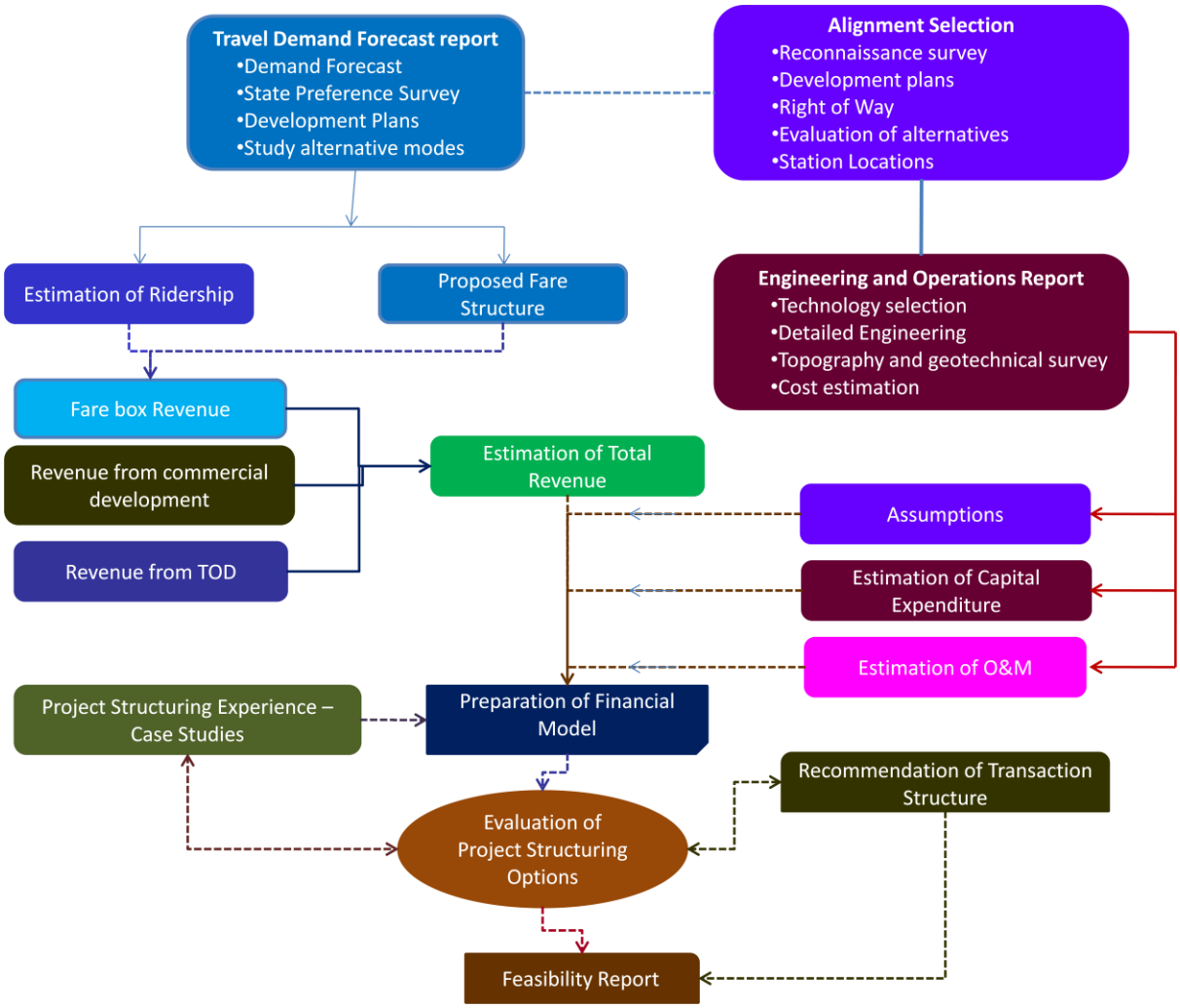


The vision of RRTS can be summarized in the following points:

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

0.4 Overall Approach for Feasibility

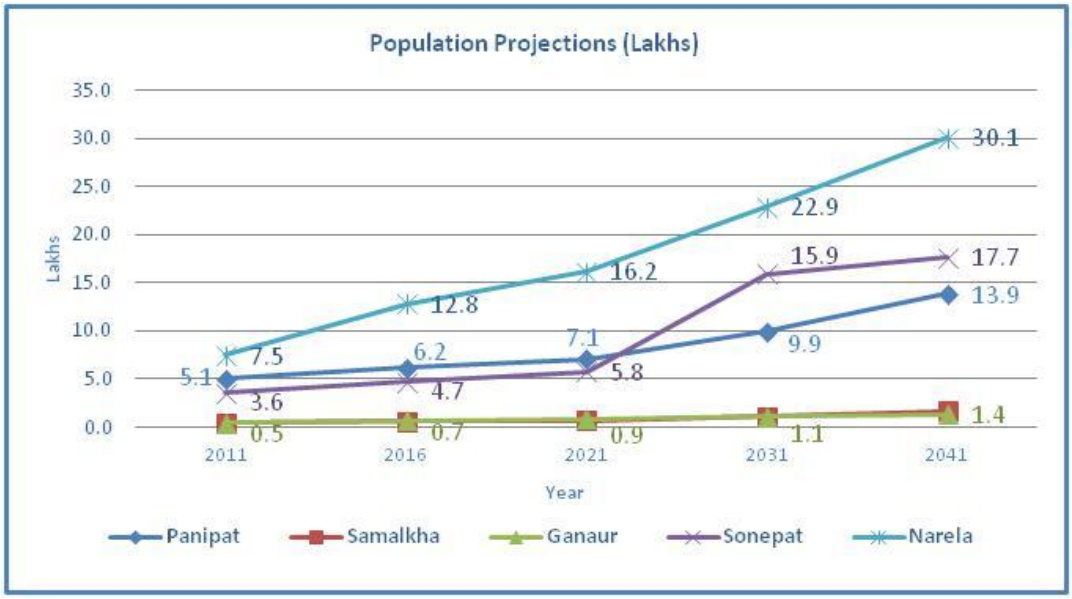
The figure below depicts the overall approach for preparation of the Feasibility Report for the RRTS Delhi Sonepat Panipat corridor.



0.5 Detailed Travel Demand Forecast Study

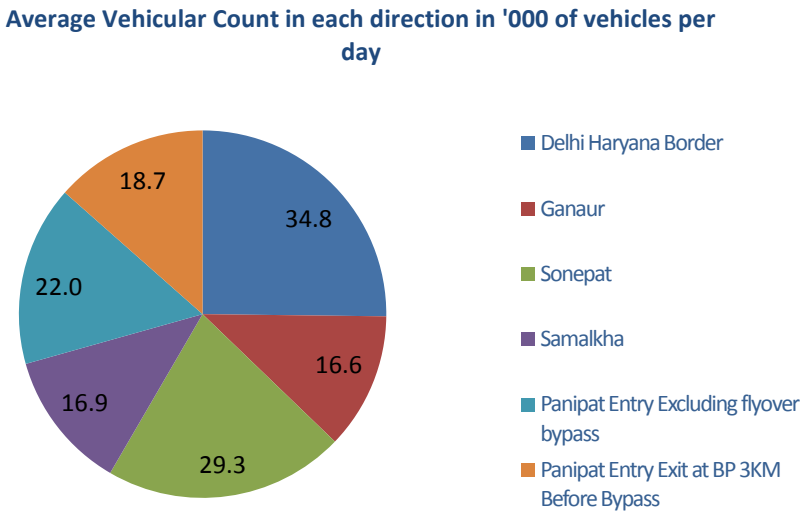
The development plans for main cities of Sonepat and Panipat along with Class-I and II towns of Ganaur and Samalkha have been studied. The development plans have projected the population for each of the towns for the year 2011 & 2021 in sync with the proposed development. Population is estimated for the horizon years 2031 and 2041 using Regression method. The demographics estimated are presented below.

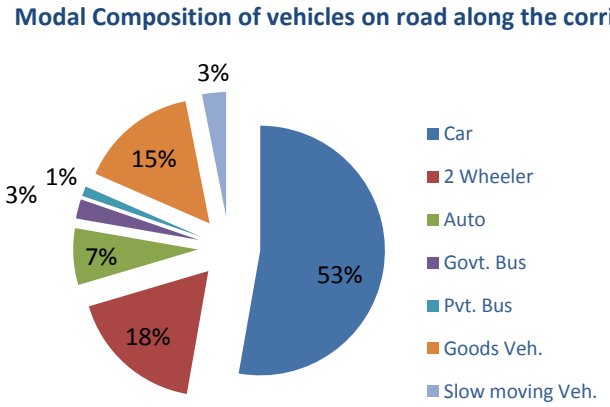
Demographic profile along the corridor



0.6 Traffic Volume

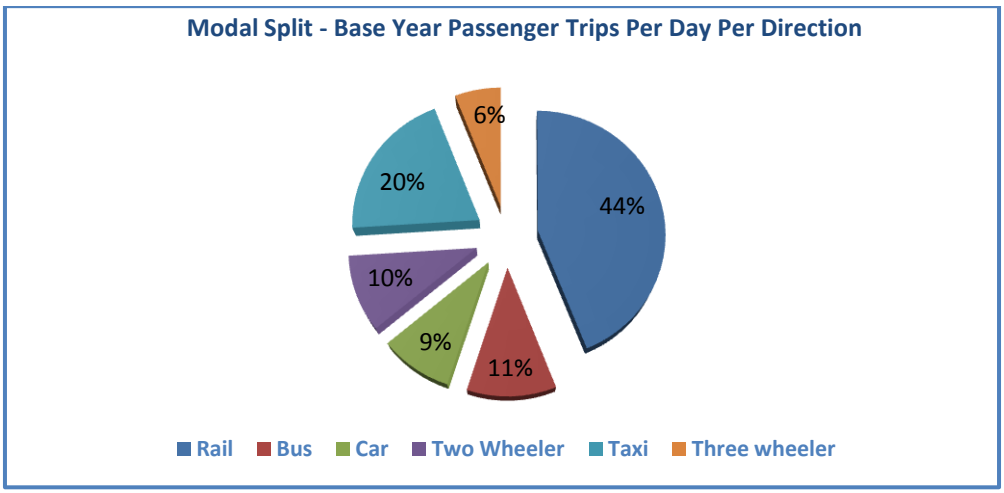
The average daily traffic and modal composition of vehicles on a typical week day in both the directions along the corridor is given below.





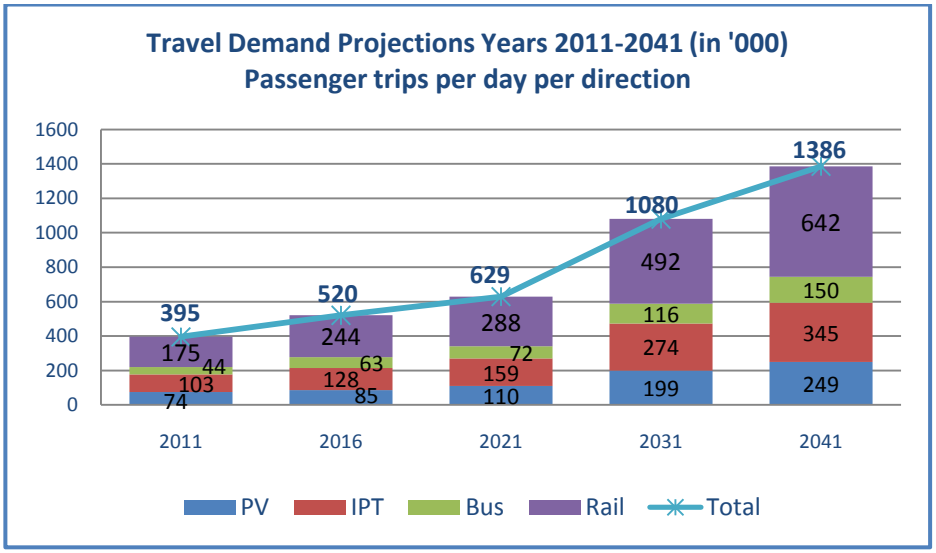
0.7 Travel characteristics of Base Year (2011) by Rail, Bus and Private Vehicles

The total passenger movement from Delhi to Panipat along the study corridor is around 3.95 lakh passengers per day. The modal share shows that maximum (44%) share of passengers is carried by rail (44%) followed by IPT (combination of two wheelers, taxi and three wheelers). The mode wise breakup of base year travel demand is presented in the following chart.



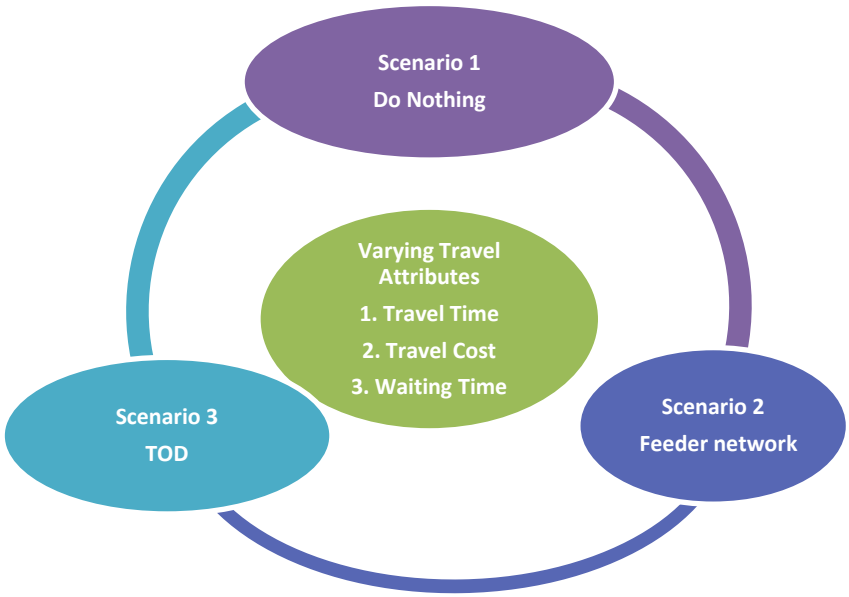
0.8 Travel Demand Forecast

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



0.9 Ridership Estimation for RRTS along the Delhi Sonepat Panipat Corridor

Stated preference surveys were conducted to arrive at binary logit mode choice model. The model is used to estimate shift from a given OD pair to RRTS based on the travel time, travel cost and waiting for that OD pair. This exercise of identifying the shift of travel from existing mode to RRTS is performed for each mode and the shift is calculated using the fares, travel time and waiting times of the existing mode to that of RRTS in the binary logit model obtained from analyzing stated preference data.



Demand has been estimated based on 74 minutes travel time between Delhi- Panipat, peak and off peak frequency as per operational plan and Rs1.1 per km fare as determined from Willingness To Pay. The fare between Delhi to Panipat City has been considered as Rs100 and the maximum fare from Delhi to IOCL Panipat has been

extrapolated based on length to Rs 110. A concessional fare (monthly pass) has also been considered for the commuters. We have assumed that the concessional fare would be 25% less than the full fare for respective journeys for the consumers. It has been assumed that 75% of the passengers would be using the full fare and 25% would be using the concessional fare (monthly pass) for commuting between Delhi Panipat

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

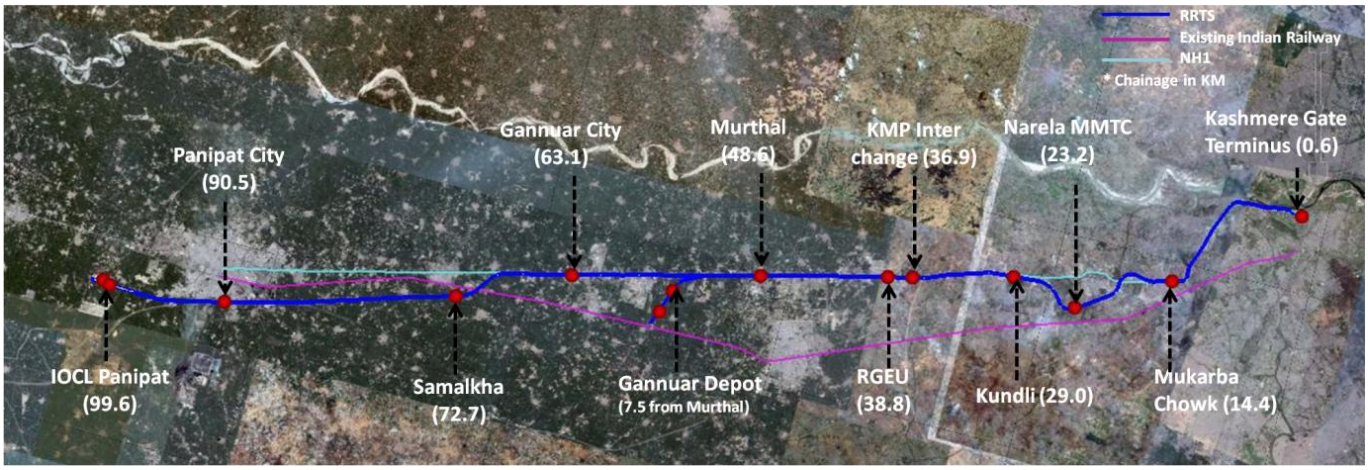
The ridership is presented in table below

Daily ridership

Year	Total ridership (in lakhs per day)
2016	3.77
2021	5.47
2031	7.79
2041	9.83

0.10 Proposed Alignment

The Delhi Sonepat Panipat RRTS alignment is proposed to start at Maharana Pratap Inter State Bus Terminus (referred to as Kasmere Gate Terminal in this report) in Delhi and ends at IOCL Panipat terminal in Haryana covering a total distance of 111.2 kms that includes a spur length of 10.6 kms at Gannaur Depot. The alignment consists of a mix of elevated (100.7 kms), underground (2.7 kms), and segregated At Grade (7.8 kms), sections across the length of the corridor. There are 12 stations and 2 depots proposed on the corridor.



The Delhi terminal of the RRTS corridor is proposed to be located underground at Kashmere Gate parallel to, and at the same level as that of new proposed phase III underground Delhi Metro station thus providing the commuters integration with Delhi Metro and Inter State Bus Terminus at Kashmere Gate. Exiting the Kashmere Gate terminus, the alignment remains underground to cross a park, residential areas and ring road and emerges on the east side of the ring road. Thereafter the alignment goes

elevated and follows ring road to reach Mukarba Chowk station in Delhi and follows NH1 thereafter towards Narela Multi Modal Transit Centre. As a multimodal transit station is proposed in Delhi Master Plan at Narela, the alignment moves westward from NH1 to integrate with Narela MMTC and then again joins back NH1 alignment to proceed northwards to Haryana. In Haryana the alignment utilizes the greenbelt along the west side of NH1 with stops at Kundli, KMP interchange (Kundli Manesar Palwal Interchange), Rajeev Gandhi Education University, Murthal and Gannuar. At Gannaur, a spur of 10.6 km length has been proposed towards the west of the main alignment for RRTS depot and Gannaur Depot station that will serve the Transit Oriented Development Zone to be developed at Gannaur. Moving northwards from Gannuar city station, the elevated main alignment moves westward to cross the Indian Railway alignment to reach Samalkha station parallel to the Indian Railway station at Samalkha. From Samalkha the alignment moves northwards to reach Panipat City station and further terminates at Panipat IOCL terminal station. Depots are proposed at Panipat IOCL terminal and Gannaur. Along the alignment three Transit Oriented Zones are proposed at (1) IOCL Panipat, (2) Samalkha, and (3) Gannaur Depot.

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

Sr. No	Stations	Station location	Distance from Previous station (KM)	Total KM
1	Kashmere Gate Terminus	Underground		
2	Mukarba Chowk	Elevated	13.8	13.80
3	Narela MMTC	Elevated	8.8	22.60
4	Kundli Border	Elevated	5.8	28.40
5	KMP Expressway interchange	Elevated	7.9	36.30
6	Rajeev Gandhi Education City (Rai)	Elevated	1.9	38.20
7	Murthal (Sonepat)	Elevated	9.8	48.00
9	Gannaur (at NH1)*	Elevated	14.5	62.50
10	Samalkha	Elevated	9.6	72.10
11	Panipat City	Elevated	17.8	89.90
12	IOCL Panipat	At Grade	9.1	99.00
8	Gannaur Depot (along the spur)*	At Grade	7.5	106.5
	Additional Length of alignment			4.70
	Total Length			**111.2**

* distance from Murthal

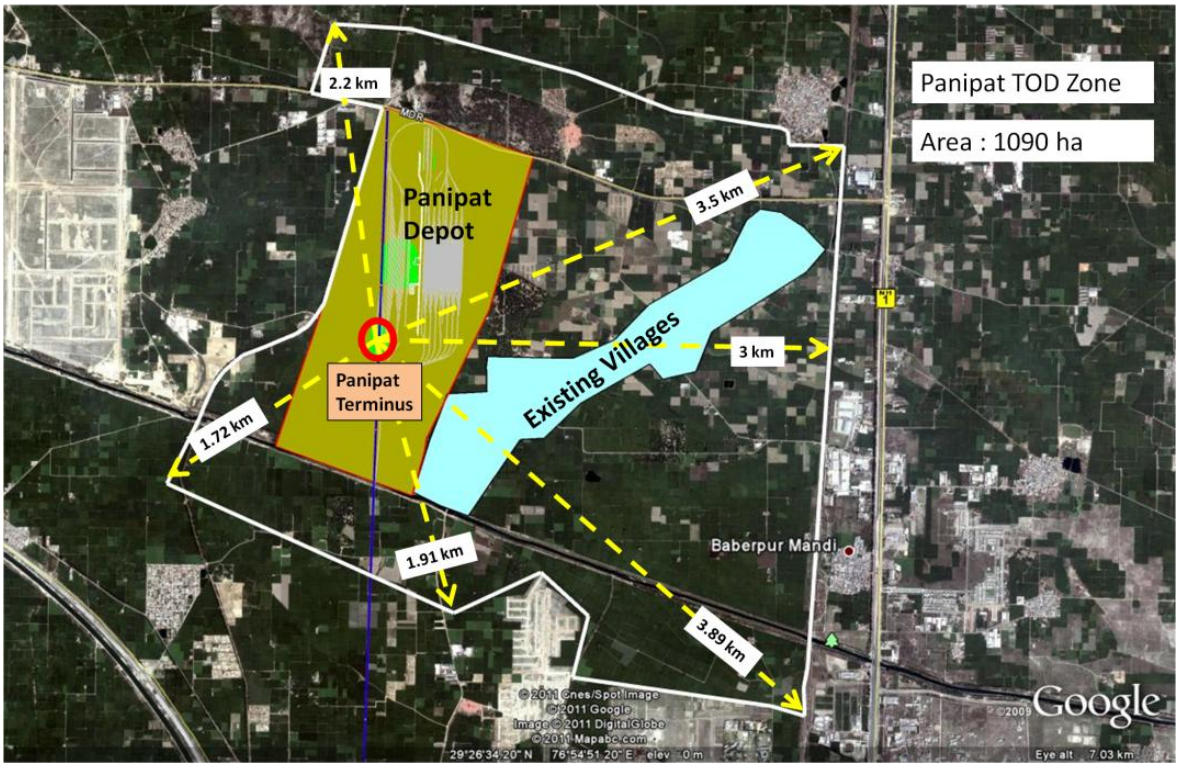
0.11 Transit Oriented Development Zones

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

Potential TOD sites

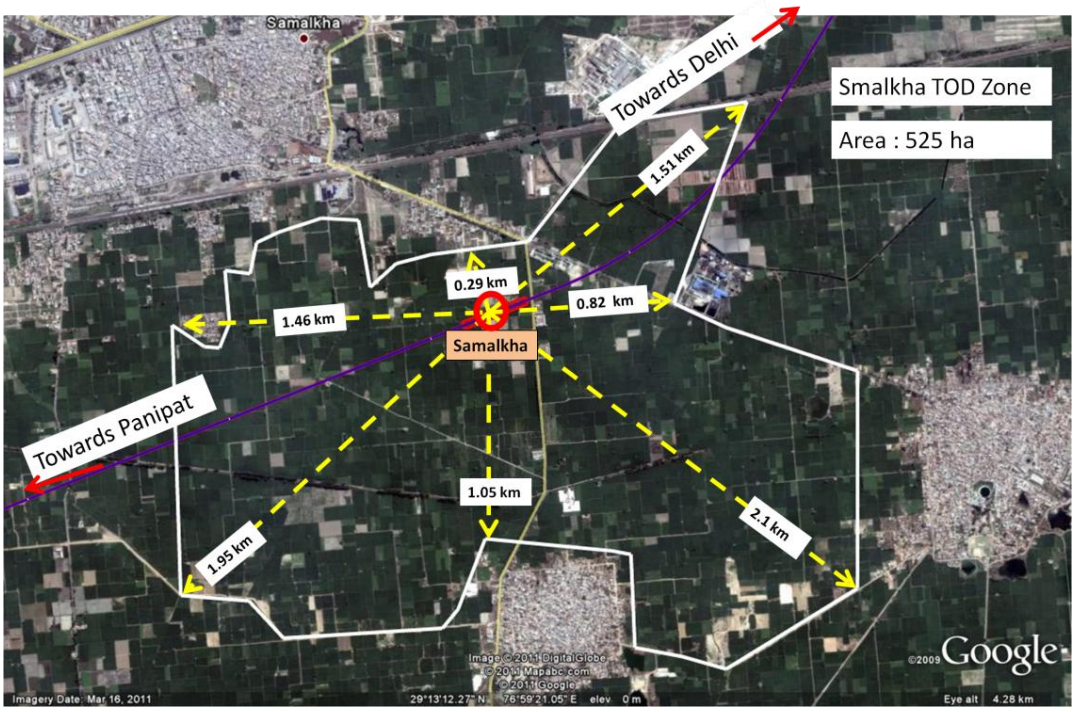
Three potential TOD sites have been in vicinity of IOCL Panipat, Samalkha and Gannaur Depot Stations.

Potential area for TOD at IOCL Panipat Depot

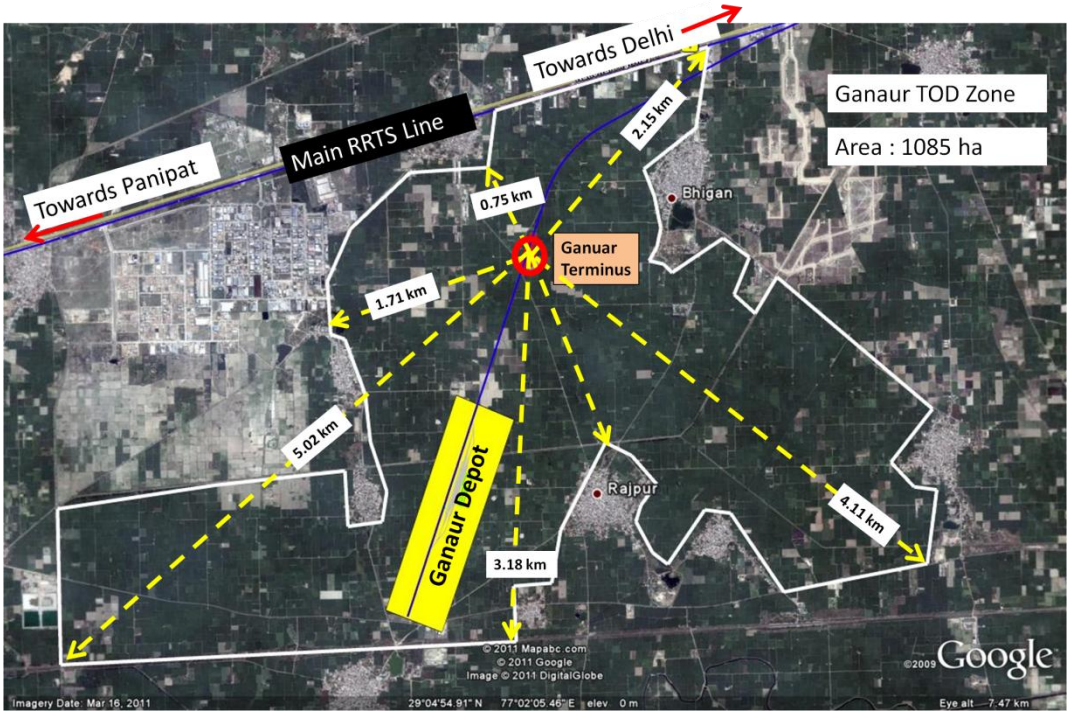


Towards Delhi

Potential area for TOD at Samalkha



Potential area for TOD at Gannuar Depot



0.12 Rolling Stock Selection

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

- operating headway of 3.5 minutes at Ultimate System Capacity (2041);
- operating headway of 4.5 minutes at Opening System Capacity (2021);
- cars of 3.7 metres external width;
- three double doorways per bodyside of 1.5 metres nominal width;
- one luggage stack per driving car;
- two luggage stacks per middle car;
- one wheelchair position per driving train;
- seat pitch of 800 mm arranged airline-style. Alternatively, the seats could be arranged front/rear facing;
- preferred maximum standing passenger density of 3 per square metre;
- no tables;
- no toilets;
- no catering facilities;
- no equipment cabinets within the saloons;
- no bicycle accommodation;
- no train crew accommodation (other than the drivers).

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

Parameter	At Opening System Capacity	At Ultimate System Capacity
Peak Hour System Capacity, PHPDT	16,281	27,683
Operational Headway, minutes	4.5	3.5
Required Train Passenger Capacity	1,252	1,628
Nominal Car Length, metres	24	24
Nominal Car Width, metres	3.7	3.7
Rail Gauge, mm	1,676	1,676

Seating Layout	2 + 3	2 + 3
Style of Seat Layout	Airline	Airline
Seat Pitch, mm	800	800
Density of Standing Passengers in Normal Service, per square metre	3	3
Number of Cars per Train	6	9
Train Length, metres (formed from 3-car units)	152	228
Train Stopping Accuracy at Stations, metres	10	10
Number of Doorways per Bodyside	3	3
Nominal Width of the Bodyside Doors, metres	1.5	1.5
Number of Luggage Stacks per Driving Car	1	1
Number of Luggage Stacks per Middle Car	2	2
Number of Wheelchair Positions per Driving Car	1	1
Number of Wheelchair Positions per Middle Car	0	0
Toilets on the Trains	No	No
Tables on the Trains	No	No
Catering Facilities on the Trains	No	No
Bicycle accommodation on the Trains	No	No
Train Crew Accommodation on the Trains (other than the drivers)	No	No
Train Type	25 kV EMU	25 kV EMU
Train Configuration	Fixed formation of 3-car units and 6-car units	Fixed formation of 3-car units and 6-car units
Nominal Laden Car Weight (heaviest car), tonne	77	77
Extreme Car Weight, tonne	95	95

Train Power with 160 km/hr maximum speed, MW	1.90	3.00
Energy Consumption for Single Journey with 160 km/hr maximum speed, kWh	2,235	3,350
Regenerative Braking Required	Yes	Yes
Cab-end gangways with close-off doors	Yes	Yes
Passenger Saloons and Driving Cabs to be Air Conditioned	Yes	Yes
CCTV in the Trains	Yes	Yes
Maximum Train Speed, km/hr	160	160
Maximum Initial Train Acceleration, m/s^2	1.0	1.0
Initial Train Acceleration to be Independent of Train Weight	Yes	Yes
Maximum Braking Rate, m/s^2	1.0	1.0
Average Service Braking Rate, m/s^2	0.5	0.5
Stop-all-stations Journey Time from Kashmere Gate to Panipat IOCL, minutes	74	74
Stop-all-stations Journey Time from Kashmere Gate to Ganaur Terminus, minutes	41	41
Number of Trains to be Provisioned	34	44
Number of Cars to be Provisioned	204	396
Track Gauge	1676mm Indian Broad Gauge	
Track Structure	ballastless track structure on main running lines	
Rails	60kg/m flat bottom	
Signalling	CATC	

The track cross section dimensions are built up as follows :

Element	Dimension	Comment
Emergency walkway	1000mm 700mm	Generally At OLE mast positions
OLE structure	300mm	
Structure clearance	2135mm	To track centreline
Track interval	4290mm	Straight track
Track interval on curves	4460mm	Minimum 400mR

0.13 Communications Systems

The Supervisory Control and Data Acquisition System (SCADA) will monitor and/or control equipment of the System including the fare collection equipment, CCTV, public and non-public Emergency Telephones (ET). It will display the alarms and will be able to control some functions of this equipment. The Remote Terminal Units (RTU) will be located in stations, substations and at the Depot

Other main components of the communications are :

- Fibre Optic Communication System
- Emergency Telephones
- Closed Circuit Television
- Passenger Information Display System
- Public Address System

0.14 Fare Collection System

For the fare collection system (FCS) a preventive maintenance schedule for each of the following system elements will be provided:

- automatic ticket vending machine (ATVM).
- automatic gate barriers (AGB).
- central and station computer system.

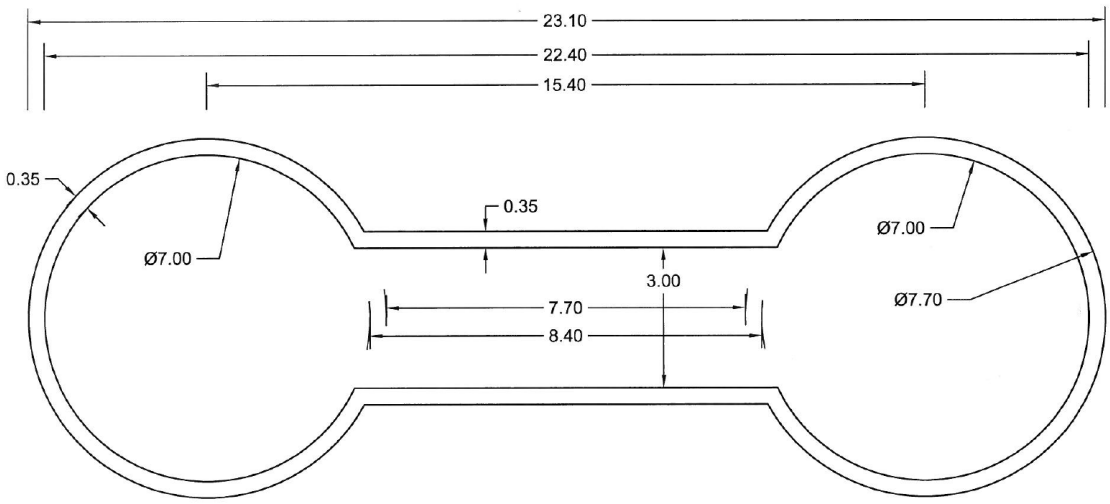
ATVMs, AGBs, station computers, central servers and computers will have self diagnostics. Preventive maintenance of the FCS consists mainly of visual inspection, cleaning and internal calibration.

0.15 Selection of Structural Form

The standard viaduct section will be formed from a precast post-tensioned concrete box girder, simply supported on single piers which are founded either on bedrock or a piled slab. The deck will carry the double track railway and will be completed by pre-cast parapets which will also form a continuous emergency walkway on both sides of the structure. Single track viaducts using similar features to the standard viaduct will be required on link lines and at stations with island platforms.

The Tunnel and Portals

For the first 2.5km length of the route out of Delhi is proposed to run underground, starting in a new station box near the existing DMRC Kashmere Gate station. Currently it is proposed that the RRTS tracks will run in twin bore tunnels with an external diameter of 7.70m.



Schematic of the Twin Bore Tunnel Section

0.16 Train operational Plan

In order to provide the required passenger capacity, the service headway could be 4.5 minutes and would be a nine minute interval service between IOCL Panipat and Kashmere Gate and a nine minute interval service between Ganaur Terminus and Kashmere Gate. Such a service will take 74 minutes between IOCL Panipat and Kashmere Gate, could be accommodated on a double track railway, and will require 29 train sets to operate. The total fleet will be 34 trains including standby trains and maintenance requirements.

0.17 Power

The RRTS: Delhi – Sonipat – Panipat railway will be a high power user. Supplies will be required for both traction and non traction systems supplied at high voltage.

Traction Power

The consumption of traction electrical power is closely related to the rolling stock characteristics, the service levels required and the permanent way geometry.

(Based on rolling stock configurations in Chapter 2)		
System Information	**2021**	**2041**
Estimated Energy Consumption per annum (MWh)	350,000	644,000

0.18 ASSUMPTIONS AND BOUNDARY CONDITIONS for Financial Analysis

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

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

Sr. No.	Particulars	Value
1	Inflation rate	5%
2	Discount rate	10%
3	Tax rate	32.45%
4	MAT	20.01%
5	80IA benefit taken from date	From COD
6	Tax holding in a block of 15 years	10 years

7	Interest rate on term loan	2%
8	Term period	20 years
9	Moratorium	Nil
10	Interest rate on future capital expenditure	10%
11	Debt equity structure for future capital expenditure	80:20
12	Repayment period for future capital expenditure	10 years

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

0.19 Revenue Estimation

Fare Box Revenue

Mode wise Comparison of Existing Fare Structure

Sr. No.	Mode	Delhi – Panipat fare (in Rs.)	Journey Time	Remarks
1	EMU – Passenger	Rs 15	2-2.5hrs	
2	Kalka Shatabdi (AC Chair Car)	Rs 285 (actual) Rs151 (Prorated)	70-80 mins	Rs 151 fare is prorated based on distance on Delhi Chandigarh full fare
3	Jan Shatabdi (AC Chair Car)	210	85 mins	
4	State Transport bus (Non AC)	65 (approx)	1.5 – 2 hrs	
5	State Transport AC Volvo Bus	200 (approx)	1.5 hrs	
6	RRTS	100	74 mins.	

Fares between the stations is based on telescopic fare structure with a minimum fare 25% of Delhi Panipat City Fare (Rs 100). A rebate of 25% on the journey fare is considered for the commuters opting for the monthly pass.

Other Revenue

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

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

Proposed Cess Rate on ToD

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

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

Sr. No.	Revenue Stream	FY2018	FY2022	FY2032	FY2042
		Rs. Million /Year			
1	Fare box	7575	13929	31307	63835
2	Revenues from station commercial	987	2101	3422	5575
3	Revenue from advertisement	76	139	313	638
4	Transaction Cess on TOD post construction	6075	5670	4232	2534
5	**Total Project Revenue**	**14713**	**21839**	**39275**	**72582**

0.20 Capital Cost Estimation

Item	Description	Units	Quantity	Rate (Rs. Crore/ per Unit)	Sub-Total (Rs. Crore)	Total (Rs. Crore)
1.0	**Land**					**3114**
1.1	Private Land	Hectare	432.0	-	3114.0	
1.2	Government land	Hectare	233.0	-		
2.0	**Civil works, Alignment and formation**					**3319**
2.1	Tunneling Work	R Km	2.240	152.9	342.4	
2.2	Ramp - underground	R Km	0.325	47.3	15.4	
2.3	Ramp - Elevated	R Km	0.975	18.5	18.1	

2.4	Elevated Viaduct	R Km	93.990	30.0	2819.7	
2.5	At grade Alignment	R Km	7.180	1.5	10.9	
2.6	Single Track Viaduct	R Km	2.800	-	-	
2.61	Single Track Viaduct	Total Km	5.000	22.5	112.5	
3.0	**Station Building**		12.0			**1472**
3.1	Underground Terminal Station	Nos.	1.0	265.0	265.0	
3.2	Elevated Stations	Nos.	9.0	113.0	1017.0	
3.3	At grade Terminal Station	Nos.	2.0	95.0	190.0	
4.0	**E&M Works**		12.0			**339**
4.1	Electro mechanical works including Lifts, Escalators, DG sets, UPS,ECS					
4.11	Underground station	Nos.	1.0	67.3	67.3	
4.12	Elevated station	Nos.	9.0	26.7	240.1	
4.13	At grade station	Nos.	2.0	13.3	26.7	
4.2	Tunnel Ventillation	R Km	1.5	3.2	4.7	
5.0	**Depot-cum-Workshop**		2.0			**206**
5.1	IOCL Panipat Depot					
5.11	Civil works, Track work, OHE	Nos.	1.0	84.6	84.6	
5.12	Plant and Machinery	Nos.	1.0	77.0	77.0	
5.2	Gannaur Depot					
5.21	Civil works, Track work, OHE	Nos.	1.0	24.1	24.1	
5.22	Plant and Machinery	Nos.	1.0	20.0	20.0	
6.0	**Permanent Way**					**722**
6.1	Ballastless track for elevated & underground alignment	R KM	104.1	6.5	674.2	
6.2	Ballasted/Embedded track for at grade allignment	R KM	17.2	2.8	48.1	
7.0	**Traction & Power Supply incl. OHE, ASS etc.**					
7.1	Under Ground Section	R KM	2.57	8.7	22.3	
7.2	Elevated & At Grade Section	R KM	120.9	6.8	821.9	
8.0	**Signalling and Telecom.**					**840**
8.1	Signalling	R KM	121.2	6.3	768.3	
8.2	Telecom.	No. of Stations	12.0	6	72.0	
9.0	**Automatic fare collection**					**56**

9.1	Ticketed Stations	No. of Stations	12.0	4.7	56.4	
10.0	**R & R**					**56**
10.1	R & R incl. Hutments and road restoration etc	R KM	111.2	0.5	55.6	
11.0	**Misc. Works**					**177**
11.1	Utilities Relocation	R KM	111.2	0.5	55.6	
11.2	Misc. civil works such as median, road signages	R KM	111.2	0.5	55.6	
11.3	Barracks for Security Staff including security equipments	Nos.	12.0	0.5	6.0	
11.4	Staff Quarters for O&M	Nos.	12.0	5.0	60.0	
12.0	**Rolling Stock**					**2142**
12.1	EMU Coaches	Nos.	204.0	10.5	2142.0	
13.0	**Miscellaneous Items**					**138**
13.1	Training	Nos.	1.0	10.0	10.0	
13.2	Spares (%of 7,8,9 & 12)	%	2%	3882.9	77.7	
13.3	Testing and Commissioning Costs	Nos.	1.0	50.0	50.0	
14.0	**Total**					
14.1	Total (Including Land Cost)	Sum (1 to 13)			**13425.2**	
14.2	Total (Excluding Land Cost)	Item 14.1 Less 1			10311.2	
14.3	General Charges incl. Design charge	% of 14.2	10311.2	5%	515.6	
14.4	Contingency	% of 14.1+14.3	13940.7	5%	697.0	
	Estimated Construction Cost on Year 2011 Basis (Excluding Land)					**11524**
	Estimated Construction Cost on Year 2011 Basis					**14,638**

Base capital cost with taxes and duties

Sr. No.	Components	Amount in Rs. Million
1	Land	3114
2	Base Construction Cost (excl. land cost & General Charges and Contingency)	103112

3	**Total Base Project Cost**	**134252**
4	Total Central Taxes	**11007**
a	Customs Duty	7159
b	Excise Duty	3848
5	Cost including Central Taxes (3+4a+4b)	145259
6	State Tax (VAT)	**6358**
7	Cost including State Tax (5+6)	151617
8	General Charges @5% on (7 -1)	6024
9	Contingency @5% on (7+8)	7882
10	**Total Cost (incl. taxes excl. IDC)**	**165522**

0.21 Operation & Maintenance Cost Estimation

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

- Staff costs
- Energy cost
- Maintenance cost

Staff Cost

Actual staff cost for FY18, FY21, FY31 and FY41 are presented below
.

Number of Staff	
Main Depot	615
Second Depot	63
Train Crew	326
Station Staff	1,308
Total Staff Number	**2,312**
Salary Cost, Rs Mil per year	**Rs Mil/year**
FY 2018	1363
FY2021	1888
FY2031	4933
FY2041	12885

Energy cost

Base energy costs (at 2011 cost levels) have been calculated for 3 blocks of years namely 2016-2021, 2021-2034 and 2035-2041. The estimation of the energy cost has been done based on the energy consumption in the following areas

- Energy consumption in traction
- Energy consumption in station
- Energy consumption in depot

Timeline	Total Consumption, kWh	Energy Cost per year, (Rs Cr)	Total Demand, kVA	Demand cost per year, (Rs Cr)	Total cost per year, (Rs Cr)
2016 to 2020	373,109,280	157.83	64,685	9.70	167.53
2021 to 2034	547,837,741	231.74	94,977	14.25	245.98
2035 to 2044	670,150,208	283.47	116,182	17.43	300.90
2044+	884,576,324	374.18	153,357	23.00	397.18

Maintenance Expenditure

For repair and maintenance of the RRTS assets, apart from staff, some material will also be used. This includes spare parts and consumables. The cost of such material which is consumed annually depends on a lot of factors such as the design of the equipment, the intensity of usage, the maintenance philosophy, the manufacturer's recommendations, renewal plans etc. The Base maintenance costs (at 2011 price levels) per annum have been estimated at a rate of 0.8% of total base capital expenditure (excluding land).

Financial Year	Maintenance cost (Rs Million)	Manpower cost (Rs Million)	Energy cost (Rs Million)
FY 2017	668	652	1034
FY 2018	1356	1363	2060
FY 2019	1424	1472	2122
FY 2020	1495	1589	2186
2021	1620	1888	2251
2022	1860	2039	3405
2023	1953	2202	3507
2024	2050	2379	3612
2025	2153	2569	3721
2026	2261	3052	3832
2027	2374	3296	3947
2028	2492	3560	4066
2029	2617	3844	4188

2030	2748	4152	4313
2031	3045	4933	4443
2032	3701	5327	4576
2033	3886	5753	4713
2034	4081	6214	4855
2035	4285	6711	5000
2036	4499	7972	6300
2037	4724	8610	6489
2038	4960	9299	6684
2039	5208	10043	6884
2040	5469	10846	7091
2041	5742	12885	7304
2042	6029	13916	7523
2043	6331	15029	7748
2044	6647	16232	7981
2045	6979	17530	10851
2046	7328	20826	11176

0.22 Project Structuring and Viability

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

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

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

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

NCRTC SPV for Panipat Delhi Structure

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

Equity Contribution Structure of Delhi – Sonepat - Panipat Project

Sl. No.	Name of Entity	Percentage (%)
1.	MoUD, Govt. of India + NCRPB	25
2.	Ministry of Railways + Govt. of India	25
3.	Govt. of National Territory of Delhi, State Govt. of Haryana	50
	Total	**100**

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

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

Role of Lenders

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

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

Role of Private Sector

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

DIMTS has carried out analysis for structuring the project under the PPP frame work, wherein the project can be developed under a suitable PPP frame work. The total life cycle investment in the project is Rs 18790 Million.

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

Role Division Between Private Sector and Government or say NCRTC

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

Project Components – Government vs Private Sector

Item	Description	Total (Rs. Crore)	Government Sector	Private Sector
1.0	Land	3114	3114	
2.0	Civil works, Alignment and formation	3319	3319	
3.0	Station Building	1472	265	1207
4.0	E&M Works	339	72	267
5.0	Depot-cum-Workshop	206	109	97
6.0	Permanent Way	722	722	
7.0	Traction & Power Supply incl. OHE, ASS etc.	844	844	
8.0	Signalling and Telecom.	840		840
9.0	Automatic fare collection	56		56
10.0	R & R	56	56	
11.0	Misc. Works	177	177	
12.0	Rolling Stock	2142		2142
13.0	Miscellaneous Items	138		138
14.0	General Charges and contingency	1213	726	487
15.0	Total	14638	9404	5234
	In % terms			
	% of Initial Investment		64%	36%
	% of Total Lifecycle Investment		50%	50%

From the above analysis we suggest that about 64% of the initial construction cost would need to be contributed by the government or multilateral financial institutions. It would be prudent to, therefore split the project to deliver optimum project structuring wherein a government entity could raise fund from Financial Institutions and its own sources with about 36% of project cost from private sector investment.

Project Structure

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

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

a) RRTS Delhi-Panipat Infrastructure Limited ("DP Infraco")
b) RRTS Delhi-Panipat Rolling stock Limited ("DP Rollco")

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

Sl. No.	Name of Entity	Investment Based on Length		Contribution Based on Initial Investment	
		%	Rs. Crores	%	Rs. Crores
	Investments by DP Infraco				
1.	MoUD, Govt. of India + NCRPB	5.9%	1,109	5.9%	1,109
2.	Ministry of Railways + Govt. of India	5.9%	1,109	5.9%	1,109
3	Govt. of National Territory of Delhi	3.0%	568	2.6%	485
4	State Govt. of Haryana	8.8%	1,650	9.2%	1,733
5	**Total by DP Infraco**	**23.7%**	**4,436**	**23.7%**	**4,436**
6	Soft Loan	40.1%	7,517	40.1%	7,517
	Investments by DP Rollco				
7	DP Rollco	36.3%	6,801	36.3%	6,801
8	**Total investment**	**100%**	**18,755**	**100%**	**18,755**

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

In the realistic scenario in which the PPP bidding can be done, the investment between DP Infraco and DP Rollco can be divided as follows.

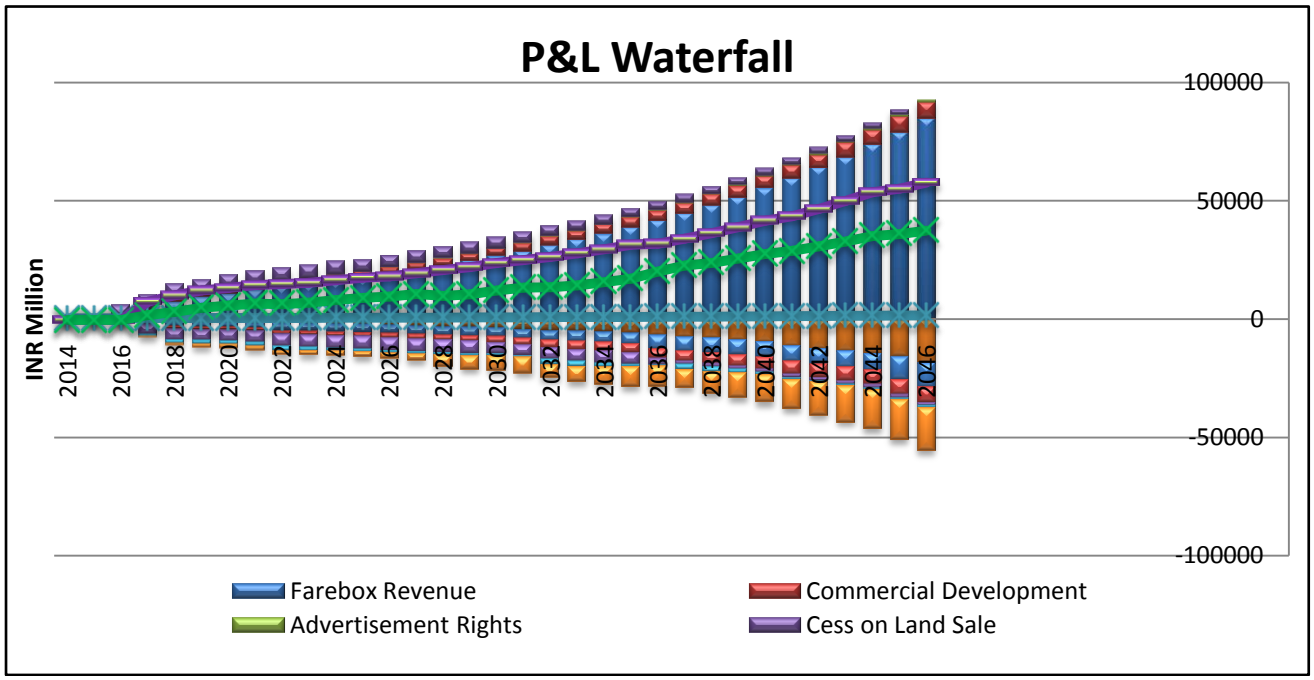
Name of Entity	%	Rs. Crores
DP Infraco	30%	5638
Soft Loan	40%	7482
DP Rollco (Private sector)	30%	5644
Total	**100%**	**18764***

*The difference in total cost from the previous table is attributable to IDC

0.23 Profit and loss account

Profit and Loss statement synopsis for key years

P&L Statement (Rs Mil)	FY18	FY22	FY27	FY32	FY37	FY42	FY46
Revenue							
Fare box revenue	**7575**	**13929**	**20882**	**31307**	**44704**	**63835**	**84883**
Revenue from commercial development	987	2101	2682	3422	4368	5575	6776
Revenues from Advertisment Rights	76	139	209	313	447	638	849
Other Revenue (from TOD Cess)	6075	5670	4860	4232	3275	2534	2064
Total Revenue	***14713***	***21839***	***28633***	***39275***	***52794***	***72582***	***94572***
Expenses							
Maintenance cost	1356	1860	2374	3701	4724	6029	7328
Manpower cost	1363	2039	3296	5327	8610	13916	20826
power cost	2060	3405	3947	4576	6489	7523	11176
Rehabilitation Grant	438	533	680	868	1107	1413	1718
Total operating expenses	***5217***	***7837***	***10297***	***14472***	***20931***	***28881***	***41048***
EBITDA	9496	14003	18336	24803	31864	43700	53523
Depreciation	4597	5087	5087	5027	1424	1424	1422
EBIT	4898	8915	13249	19776	30439	42276	52102
Interest on long term loan	*1428*	*1693*	*752*	*1894*	*1605*	*0*	*0*
Interest on short term loan	*142*	*240*	*313*	*429*	*566*	*776*	*994*
PBT	3328	6983	12184	17454	28269	41500	51107
Tax	666	1,397	2,438	4,944	7,005	12,747	16,420
PAT	**2662**	**5586**	**9746**	**12510**	**21264**	**28753**	**34688**



0.24 Cash flow and return for the project

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

iculars (All figures in Rs Mil)	FY13	FY14	FY15	FY16	FY17	FY21	FY22	FY27	FY32	FY37	FY42	FY46
Inflow												
PAT	0	-360	-379	-397	1383	6098	5586	9746	12510	21264	28753	34688
Interest	0	0	0	0	801	1464	1932	1065	2323	2171	776	994
Depreciation	0	0	0	0	4597	4720	5087	5087	5027	1424	1424	1422
Total Inflow	**0**	**-360**	**-379**	**-397**	**6781**	**12282**	**12605**	**15898**	**19859**	**24859**	**30954**	**37104**
Outflow												
Capital Investment	-24986	-59527	-58152	-40558	-4328	-3862	-11586	0	-24015	-25024	0	0
IDC	0	0	333	1246	733	0	0	0	0	0	0	0
Total Outflow	-24986	-59527	-57819	-39311	-3595	-3862	-11586	0	-24015	-25024	0	0
Net flow	**-24986**	**-59887**	**-58198**	**-39709**	**3186**	**8420**	**1019**	**15898**	**-4155**	**-165**	**30954**	**37104**
Project IRR (Post Tax)	**5.78%**											

Particulars (All figures in Rs Mil)	FY13	FY14	FY15	FY16	FY17	FY21	FY22	FY27	FY32	FY37	FY42	FY46
Inflow												
PAT	0	-360	-379	-397	1383	6098	5586	9746	12510	21264	28753	34688
Depreciation	0	0	0	0	4597	4720	5087	5087	5027	1424	1424	1422
Principal Repayment	0	0	0	0	1879	3759	10225	3759	10225	8346	0	0
Total Inflow	**0**	**-360**	**-379**	**-397**	**7860**	**14576**	**20898**	**18592**	**27762**	**31034**	**30178**	**36109**
Outflow												
Equity outflow	-18989	-45240	-3784	0	0	-772	-2317	0	-4803	-5005	0	0
Total Outflow	**-18989**	**-45240**	**-3784**	**0**	**0**	**-772**	**-2317**	**0**	**-4803**	**-5005**	**0**	**0**
Net flow	**-18989**	**-45601**	**-4163**	**-397**	**7860**	**13804**	**18581**	**18592**	**22959**	**26029**	**30178**	**36109**
Equity IRR	**16.08%**											

0.25 Debt service and DSCR

The debt servicing of the soft loan can be under taken from the development cess on TOD levied on sale of built up area as described in the Revenue estimation chapter. The table below provides the Net Present Value (@10% discount factor) of the revenues generated from TOD cess and principal and interest repayment of the soft loan from the multilateral agencies

Cess on TOD	Rs Millions NPV@10%	Remarks
Revenue from Cess		
During construction period	10,231	The cess collected during construction phase can be used to fund the equity contribution by the Govt for the project
During Operations period	26,956	The cess collected during the operations period can be utilized for servicing the soft loan
Debt Servicing		
Principal Repayment	17,242	
Interest Repayment	4,484	
Total Debt servicing	21,726	
Surplus after debt servicing	5229	Surplus funds after debt servicing may be distributed among the shareholders

The Average Debt service coverage ratio for the project is 3.42, with minimum DSCR observed at 1.04

0.26 Total Lifecycle Investment

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

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

Item	Description	Total (Rs. Crore)	Govt (Rs Crs)	Pvt. (Rs Crs)
1.0	Land	3114	3114	
2.0	Civil works, Alignment and formation	3319	3319	
3.0	Station Building	1472	265	1207
4.0	E&M Works	339	72	267
5.0	Depot-cum-Workshop	206	109	97
6.0	Permanent Way	722	722	
7.0	Traction & Power Supply incl. OHE, ASS etc.	844	844	
8.0	Signalling and Telecom.	840		840
9.0	Automatic fare collection	56		56
10.0	R & R	56	56	
11.0	Misc. Works	177	177	
12.0	Rolling Stock	2142		2142
13.0	Miscellaneous Items	138		138
14.0	General Charges and contingency	1213	726	487
15.0	**Total**	**14638**	**9404**	**5234**
	% component on initial construction cost		**64%**	**36%**
16	IDC and Margin money	270		270
17	Future investment	2512		2512
18	Replacement cost	1370		1370
19	**Total Lifecycle investment**	**18790**	**9404**	**9386**
	% component on total lifecycle cost		**50.05%**	**49.95%**

0.27 Economic Internal Rate of Return (EIRR)

The benefits vehicle operating cost savings, time savings due to increased speed and environmental benefits with improved environment are added together to get the total savings. The net cash flow statements are presented in table below**.** The rate of return considered desirable for the transport infrastructure project in India is 12 percent. As EIRR of proposed RRTS facility is 22.31 %, which is above 12 percent cut-off rate, the project is economically viable.

0.28 Recommendations and Way Forward

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

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

For this purpose the 10% stake in DPRollco by DPInfraco assumes great signification since DPInfraco will bid out the project, based on the valuation of equity of DPRollco. This would be by way of positive or negative valuation for nominal 10% of DPRollco by the Concessionaire who shall have the controlling stake in the DPRollco.

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

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

A. Information of DPInfraco with equity share holding with percentage as suggested in the report
B. Setting up of DPRollco with minimum capital charges are required in terms of company law
C. Commencement of negotiation with financial institution and Government of India for obtaining soft loan.
D. Selection of suitable transaction advisory:
    i. Commencement dialogue with Government
    ii. Commencement with bidding process
E. Inviting state governments to obtain necessary equity stake in the Infraco.
F. Declaration of Transit Oriented Development zones
G. Preparation of Development Plans based on ToD Areas identified by this report within a timeframe say 3 months of release of this report
H. Legislation for collection of cess from ToD areas
I. Land acquisition where required for the project infrastructure area
J. Identification and marking of alignment on the green belt in Haryana

1. INTRODUCTION

1.1 National Capital Region

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

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

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

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

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

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

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

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

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

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

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

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

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

Figure 1-1 National Capital Region

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

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

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

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

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

1.2 Background of the Study

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

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

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

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

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

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

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

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

1.3 Vision of RRTS

- An optimized hi-speed link to suit transport demand requirements
- A high quality transport system having predominantly seated accommodation and good comfort level for passengers
- Broad gauge track for wider coaches for interoperability with existing railway networks
- Coaches must meet standard Indian structure profile

- Optimized locations of stations for ease of access to commuters and to serve maximum volume of ridership
- Optimize route and ridership needs so as to achieve good operating speeds
- Optimize the number of stops in concordance with the desired operating speed
- The operating pattern may include both non-stop and stopping at all stations journeys. The non-stop journey to be in the order of 45-50 minutes for the RRTS corridor
- The Delhi terminus may be located for interchange with the existing Delhi Metro network or any other separate continuing link with other alignments in the RRTS
- Interchange with other MRTS corridors including the development of feeder systems to other MRTS corridors

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

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

1.4.1. Scope of work

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

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

a) Financial Analysis of the study covering the following:

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

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

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

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

v.) Identifying sources of funding for the project.

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

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

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

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

i.) Travel Demand Forecast Report

ii.) Existing Condition Analysis Report

iii.) Alignment Options and Proposed Alignment Report

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

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

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

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

1.4.2. Structure of Feasibility Report

This report is laid out into Chapters; a summary of each section is detailed below:

1. Chapter 1: Introduction: The current section provides the background and objectives of the project, scope of work, deliverables and milestones achieved under the project and report structure.
2. Chapter 2: Approach and Methodology - This section provides the overall approach and methodology of Financial Analysis / Business Plan.
3. Chapter 3: Recommendations from Travel Demand Forecast study - This section provides a summary of the travel demand forecast study conducted under the assignment along with estimated ridership figures.
4. Chapter 4 – Review of present railway and NH1 alignment:- This section provides the summary of Existing Condition Analysis report submitted earlier as a part of this Assignment
5. Chapter 5: Proposed Alignment - This section provides an overview of the methodology followed to finalize the alignment, the proposed alignment & station locations. This Chapter summarizes the Proposed Alignment Report submitted earlier as a part of this assignment. The chapter also describes the station locations along the corridor alongwith the Transit Oriented Development strategy and requirement for the project.
6. Chapter 6: Key Inputs from Engineering and Operations Study - This section provides an overview of the detailed engineering study conducted for the

establishing the technical feasibility of the project. This chapter summarizes the key technical parameters related to requirement of rolling stock, signaling systems, civil works, station design, power systems that have been finalized for the project.

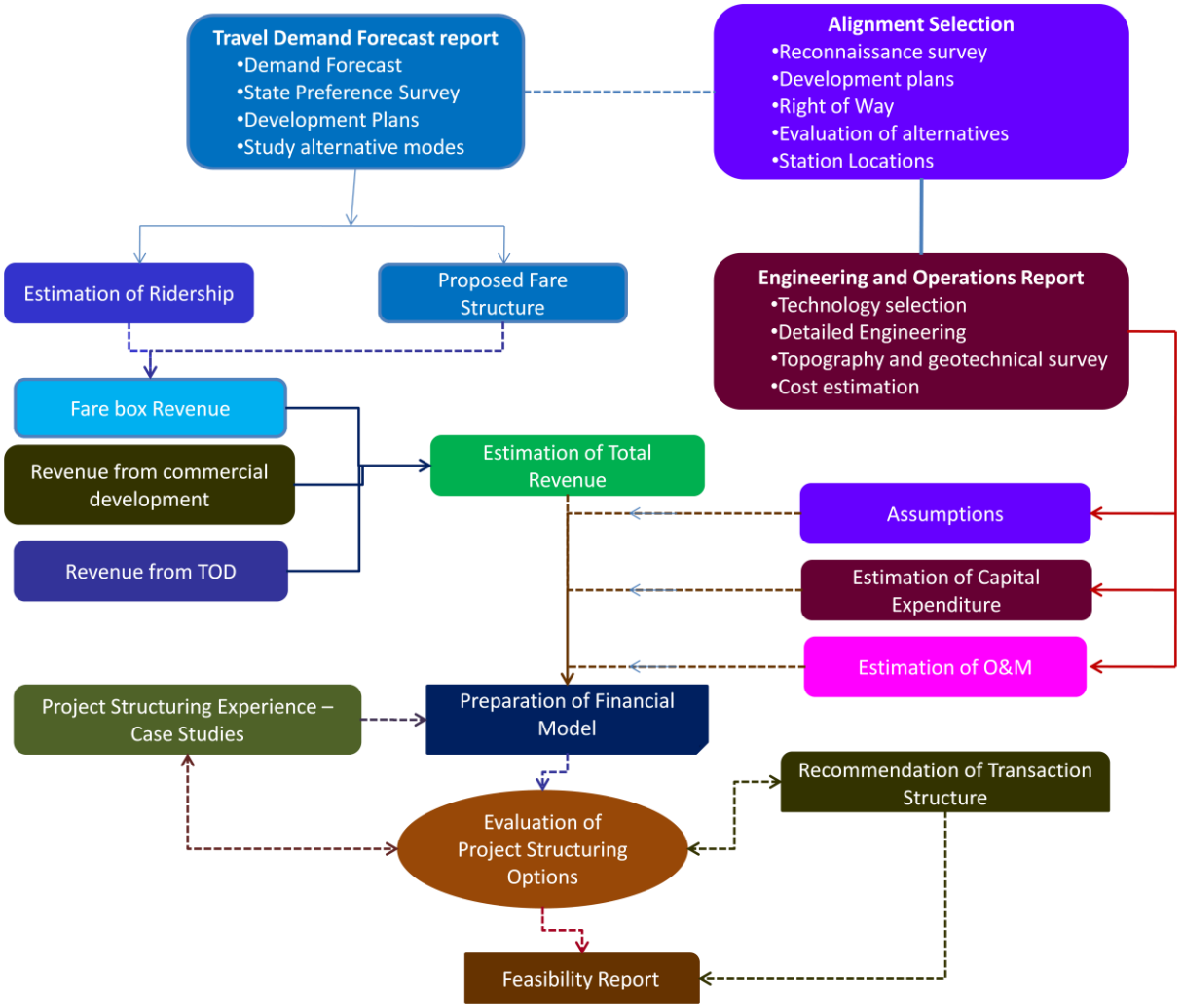
7. Chapter 7: This chapter provides details of assumption and inputs taken for the financial model
8. Chapter 8: This chapter provides details of revenue estimates from farebox and other revenue sources identified for the project.
9. Chapter 9: Capital cost estimation - This section estimates the capital cost for the project and provides information on the basis for estimation of capital cost.
10. Chapter 10:- Operations and Maintenance cost estimation: This chapter details the O&M cost estimation for the project.
11. Chapter 11: Project Structuring and Viability - This section provides a detailed analysis of the financial feasibility of the project under various input scenarios and assumptions. This chapter calculates Internal Rate of Return for the project. The chapter also provides various options of structuring the project including PPP alternatives. Also the chapter gives an overview of project structures and funding mechanisms of similar urban transport rail based PPP projects across the country. The section also tries to identify the potential funding sources for the project. The role of government support in terms of administrative support, policy interventions for the project has also been explained.
12. Chapter 12: This chapter details the economic viability of the project calculating the EIRR for the project.

2. APPROACH AND METHODOLOGY

2.1 Overall Approach for Feasibility

The figure below depicts the overall approach for preparation of the Feasibility Report for the RRTS Delhi Sonepat Panipat corridor.

Figure 2-1 Approach and Methodology



2.1.1. Development of Financial Model

DIMTS has developed a detailed financial model that integrates the financial inputs related to investments and estimates of revenue from ridership and other sources based on the Engineering and Operations Report and Travel Demand Forecast Report undertaken as a part of this assignment. Based on estimates from the aforesaid traffic study, estimates of ridership over the horizon period of 30 years have been prepared. Suitable fare structure has been prepared enabling calculation of the potential revenues from passengers. Further revenue from commercial development, an essential part of the station complex and from development of Transit Oriented Development has been assessed and incorporated in the revenue projections. The financial model has been used to develop various scenarios related to variations in capital cost, phasing of expenditure, sensitivity related to fare structure etc.

2.1.2. Project Structuring and Viability

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

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

3. RECOMMENDATIONS FROM TRAVEL DEMAND FORECAST STUDY

3.1 Detailed Travel Demand Forecast Study

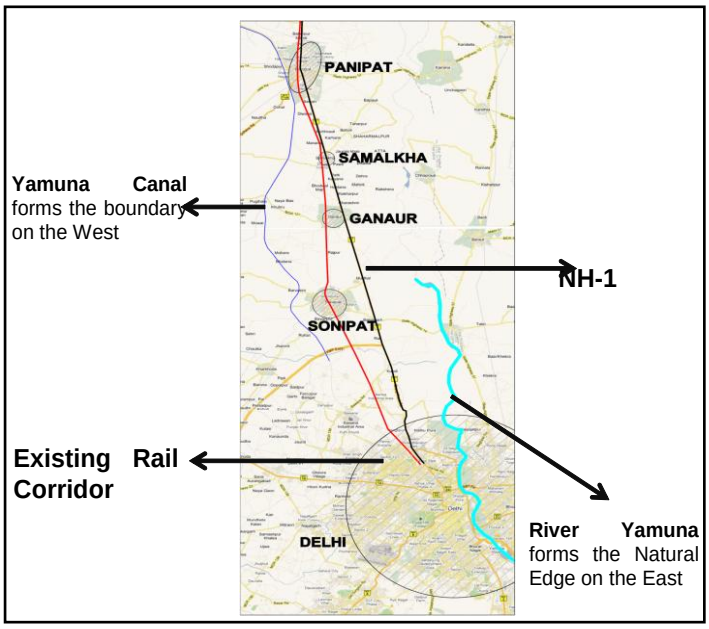
The Travel Demand Forecast Study has been conducted as a part of the preparation of a Feasibility Report followed by Detailed Project Report for development of Regional Rapid Transit System (RRTS) for Delhi – Sonepat – Panipat Corridor for a rail based transportation system integrated with multi modal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

3.2 Existing Connectivity on the Project Corridor

The Delhi-Sonepat-Panipat project corridor is in the states of Haryana and Delhi. The cities of Delhi and Panipat are connected through NH1 (6/8 lane highway) and Indian Railways trunk line. The cities and towns that lie in between Delhi and Panipat served by NH1 and the Indian Railway trunk line are Sonepat Ganaur, Samalkha, Kundli and Rai. It has been observed that most of the settlements/ development in these cities has taken place between the NH1 and Indian Railway corridor that provide connectivity between these cities as well as connectivity with Delhi and Panipat.

Figure 3-1 Project Location Map

The project corridor is bound by the River Yamuna on the eastern fringe and the Western Yamuna Canal on the western side. It is generally observed that there is not much population to the east of NH-1, and almost all the city centres in Haryana state are located to the west of NH-1 upto Ambala. The Yamuna River serves as the boundary between the states of Haryana and Uttar Pradesh. The western Yamuna Canal, NH-1 and the existing Indian Railway line are defined, continuous alignments between Delhi to Panipat and beyond.



3.3 Surveys and Studies

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

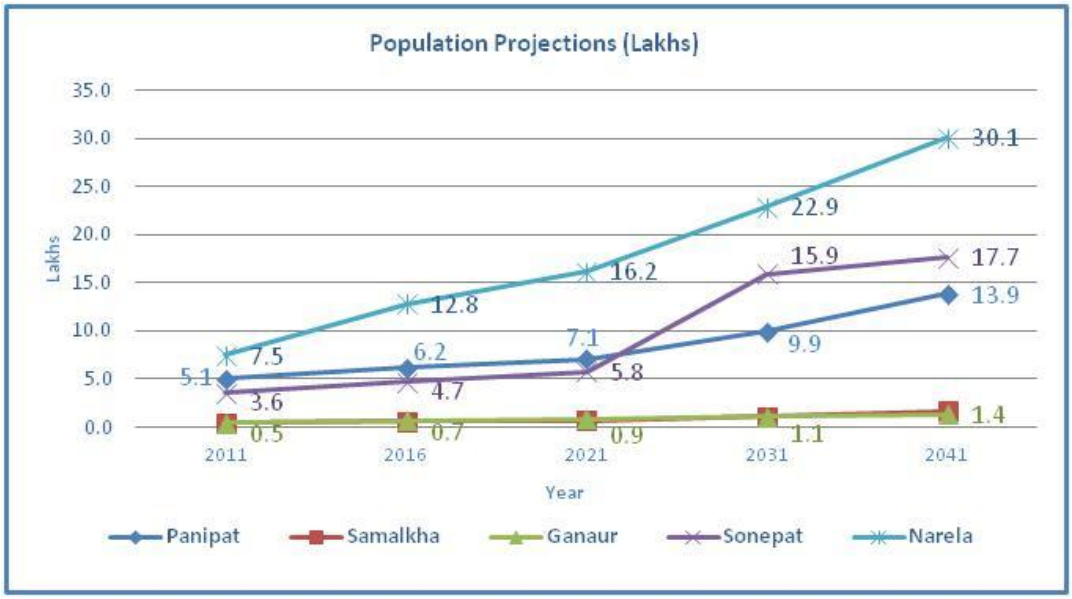
Table 3-1 : Details of Traffic Surveys

Sl. No.	Survey Title	Days	Quantum
1	Origin Destination Surveys	2 week days & 1 week end	21 locations including rail and bus stations
2	Passenger Head Count surveys	2 week days & 1 week end	16 locations including rail and bus stations)
3	Classified Traffic Volume Count Survey	16 hours	6 locations (mid block)
4	Occupancy Survey	-	6 locations
5	Stated Preference Survey	-	Conducted about 12500 enumerations among various modes

3.4 Demographic Profile along the Corridor

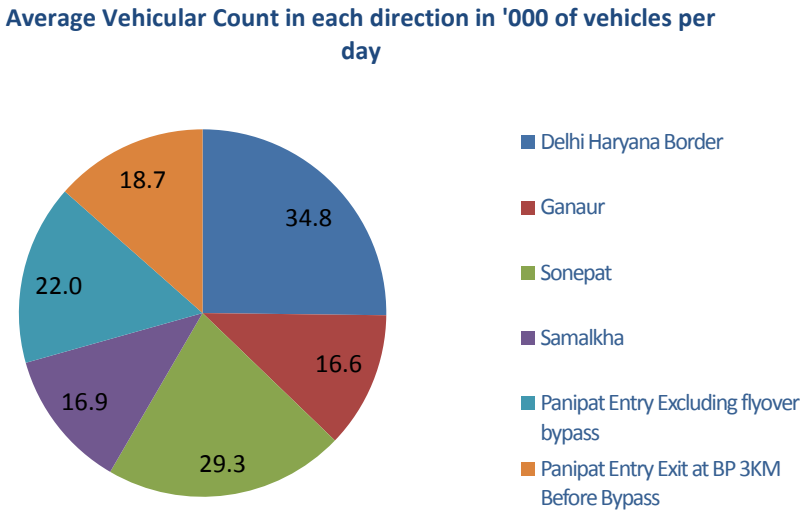
The development plans for main cities of Sonepat and Panipat along with Class-I and II towns of Ganaur and Samalkha have been studied. The development plans have projected the population for each of the towns for the year 2011 & 2021 in sync with the proposed development. Population is estimated for the horizon years 2031 and 2041 using Regression method. The demographics estimated are presented below.

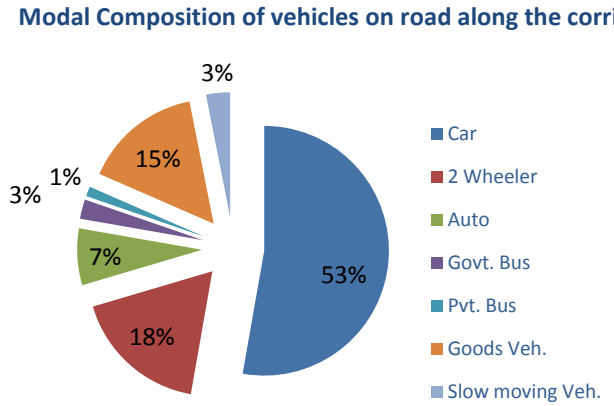
Figure 3-2 Demographic profile along the corridor



3.5 Traffic Volume

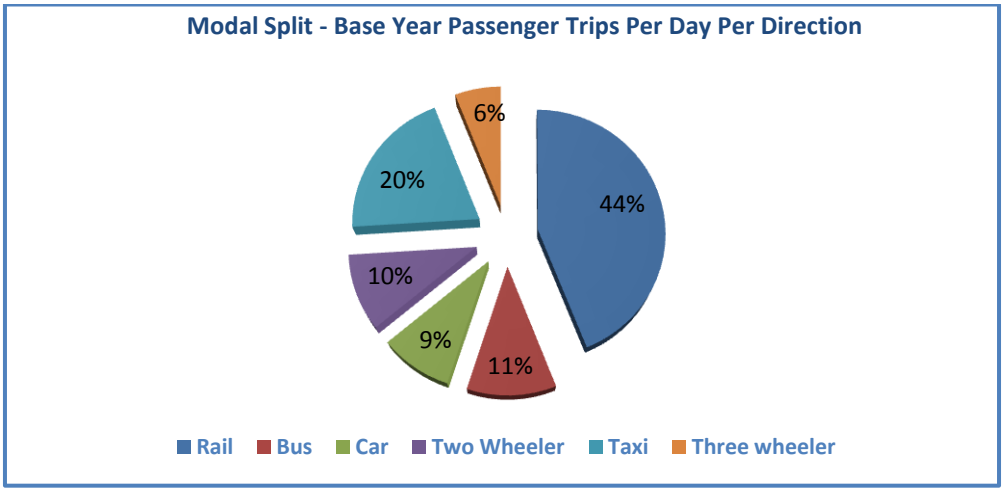
The average daily traffic and modal composition of vehicles on a typical week day in both the directions along the corridor is given below.





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

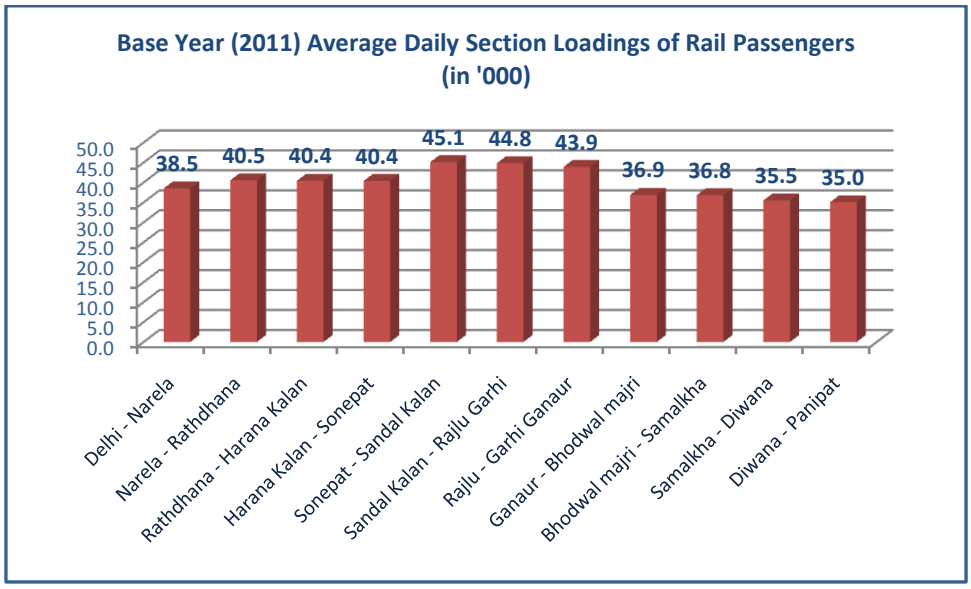
The total passenger movement from Delhi to Panipat along the study corridor is around 3.95 lakh passengers per day. The modal share shows that maximum (44%) share of passengers is carried by rail (44%) followed by IPT (combination of two wheelers, taxi and three wheelers). The mode wise breakup of base year travel demand is presented in the following chart.



The detailed breakup of the passenger movement along various sections of Railway and Road along the Delhi – Sonepat – Panipat corridor are presented in the following paragraphs.

3.5.2. *Railway Passengers*

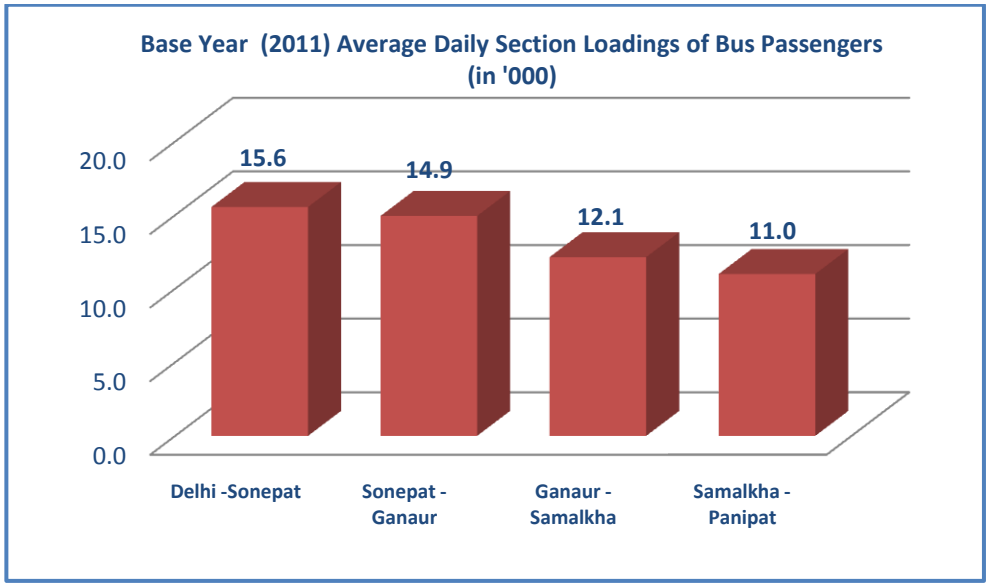
As part of commuter OD survey a total of nearly 11,000 rail passenger were interviewed for two week days and one week end at railway stations along the corridor. Based on this, the OD Matrix of daily rail passengers (commuters) along the corridor has been estimated. Sectional loadings are presented.



3.5.3. Bus Passengers

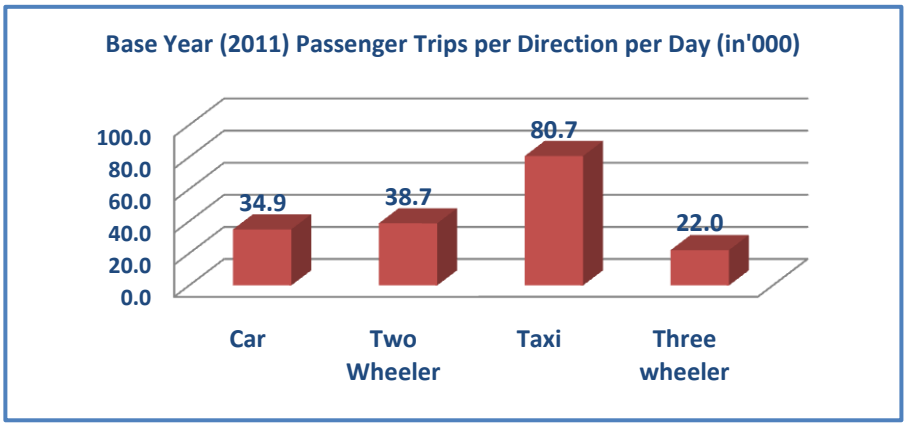
As part of commuter survey a total of nearly 5,000 bus passengers were interviewed for two week days and one week end at Delhi, Sonepat and Panipat ISBT's respectively along the corridor. Based on this, the O-D Matrix of daily bus passengers

along the corridor has been constructed. Sectional loadings are presented in the following chart.



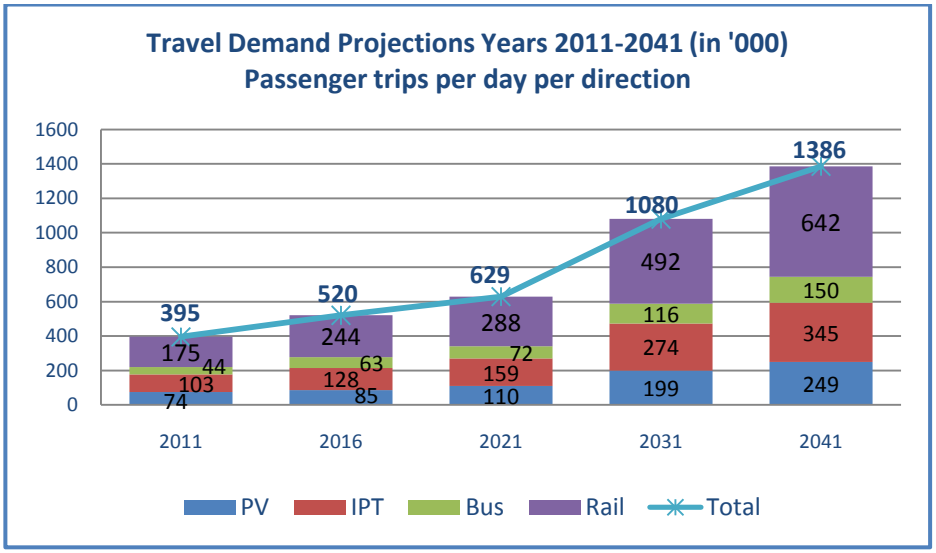
3.5.4. *Private Vehicles (PV) and Intermediate Public Transport (IPT) Passengers*

The private vehicle O-D survey was conducted on highway at various locations along the Sonepat and Panipat study corridor. As part of private vehicle survey a total of nearly 3,200 cars, two wheeler, three wheeler and taxi passenger were interviewed. Based on that survey, the OD pattern of car, two wheeler and IPT passengers has been constructed and presented below.



3.6 Travel Demand Forecast

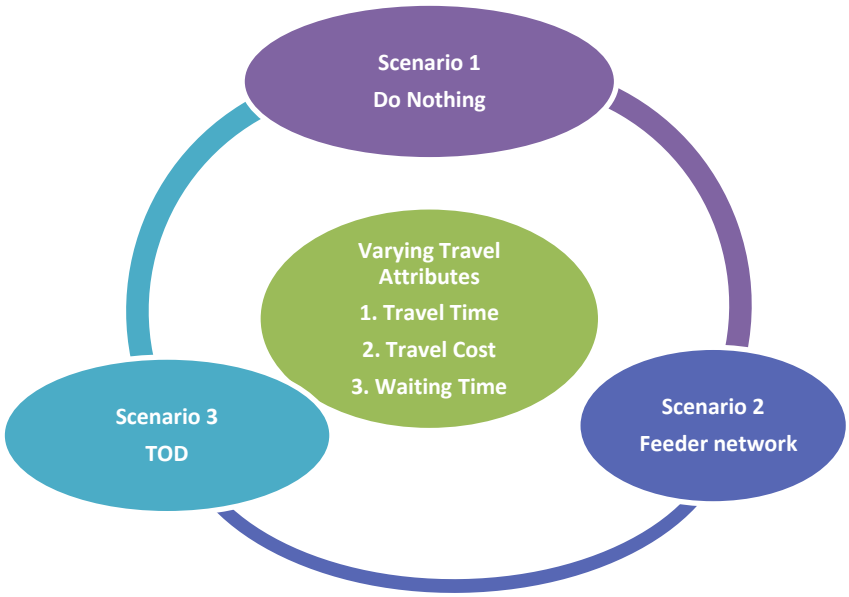
Travel demand by various modes is forecasted for all the horizon years 2016, 2021, 2031, 2041.



3.7 Ridership Estimation for RRTS along the Delhi Sonepat Panipat Corridor:

Stated preference surveys were conducted to arrive at binary logit mode choice model. The model is used to estimate shift from a given OD pair to RRTS based on the travel time, travel cost and waiting for that OD pair. This exercise of identifying the shift of travel from existing mode to RRTS is performed for each mode and the shift is calculated using the fares, travel time and waiting times of the existing mode to that of RRTS in the binary logit model obtained from analyzing stated preference data.

To understand the proposed shift of passengers from the current mode of transport to the new RRTS three scenario's were built:



3.7.1. Travel Demand Forecast Scenarios

Travel Demand Forecasts were developed as part of ridership study based on aforementioned scenarios. These scenarios cover passenger usage from the foreseen opening of the railway in 2016 with the influence of three growth types as follows:

- "Do Nothing" where passengers move naturally from the existing alternative transport methods to the railway;
- "Feeder" where bus feeder services are provided to a number of the railway stations;
- "Feeder and TOD" where, in addition to the feeder services, the additional passenger usage due to Transit Oriented Development (TOD) is included. A number of TOD zones have been investigated along the railway route.

In addition to these scenarios, the Travel Demand Forecast Study examines 12 Cases of travel attributes for travel time, travel cost and waiting time. Case 1 uses short travel time, low travel cost and short waiting time and hence produces the highest passenger numbers. At the other extreme, Case 12 uses long travel time, high travel cost and long waiting time and hence produces the lower passenger numbers.

3.8 RRTS Parameters and Estimates of Ridership

While the scenarios explained above provided a range of forecasts under various parameters, the ridership used for estimating revenue was based on fare levels (travel cost) derived from revenue optimization and willingness to pay of users. The travel time and frequency was also adopted from finalized operational plan in which RRTS simulations were conducted. The impacts of providing concessional fares were also accounted while finalizing ridership. The final ridership is presented in the table below.

This is based on 74 minutes travel time between Delhi- Panipat , peak and off peak frequency as per operational plan and Rs1.1 per km fare as determined from Willingness To Pay. The fare between Delhi to Panipat City has been considered as Rs100 and the maximum fare from Delhi to IOCL Panipat has been extrapolated based on length to Rs 110. A concessional fare (monthly pass) has also been considered for the commuters. We have assumed that the concessional fare would be 25% less than the full fare for respective journeys for the consumers. It has been assumed that 75% of the passengers would be using the full fare and 25% would be using the concessional fare (monthly pass) for commuting between Delhi Panipat

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

Based on above, the ridership is presented in table below

Table 3-2 : Daily ridership

Year	Total ridership (in lakhs per day)
2016	3.77
2021	5.47
2031	7.79
2041	9.83

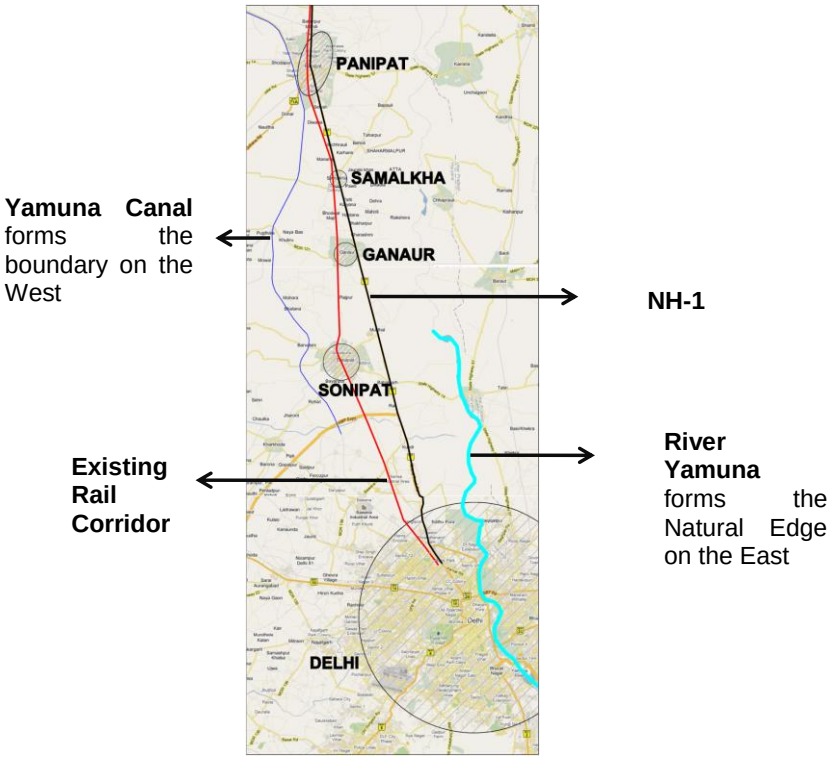
4. REVIEW OF PRESENT RAILWAY AND NH1 ALIGNMENT

4.1 Introduction

The Existing Condition Analysis report has been submitted as a deliverable as a part of this assignment. This chapter presents a summary of the Existing Condition Analysis report wherein the present Indian Railway alignment and the NH1 alignment have been evaluated for suitability for RRTS Delhi Panipat link.

4.2 Background

There are two major existing transport corridors linking Panipat and Sonepat with Delhi; (i) Indian Railway from Old Delhi to Ambala and (2) National Highway NH-1. Both these alignments generally follow flat or gently undulating landform at-grade, with grade separation at some important intersections with side roads. Survey for existing condition analysis was undertaken to investigate the feasibility of utilizing either of these existing corridors as the basis for the RRTS alignment.



4.3 Use of existing Indian Railway Alignment

The existing railway corridor is predominantly two track, running at-grade from Old Delhi Station up to Panipat. runs generally at-grade through flat or gently undulating topography. It is approximately 89 km long with a total of 16 stations throughout its entirety. A number of the existing stations have four tracks to enable passing loops within the platform areas. The existing journey time from Old Delhi to Panipat Junction averages in the region of 2 hours due to stopping at all the intermediate stations.

Detailed information regarding number of stations, level crossings, bridges, road overbridges, underbridges etc and curves along the existing Indian Railway Delhi Panipat corridor has been studied and collated. This information is summarized below:

Number of stations: 16

Number of level crossings – 48

Number of Major Bridges – 19

Between the comparatively large settlements, the railway network passes through open countryside where manually operated level crossings exist at intersections with side roads. On the existing railway corridor, RRTS alignment can be developed on the eastern side to take advantage of the direction of existing track curvature. However, at Delhi, Sonepat and Panipat, acquisition of land would be required. Large construction work adjacent to the existing railway network could also potentially cause major disruption to the operation of the railway during construction. Further, slewing of the existing track and/or demolition of adjacent property would also be required to provide land for RRTS. Also the RRTS would travel at comparatively high speed as compared to Indian Railway. This may require overhaul in the signaling system that is currently being used.

4.4 Use of existing NH1 Alignment

The NH-1 road has 6 lanes and some improvements (mainly grade separation at existing intersections) are currently under construction. NH 1, similar to existing railway network, passes through large urban settlements and also has sharp curves. Both the aforesaid factors are not amenable to development of high speed rail network.

Further at Panipat, Samalkha and Gannaur, overhead bypass (flyovers) over the city have been developed, with parallel connector roads providing access to the local network. The aforesaid developments significantly reduces the option of construction of RRTS along this alignment.

However, in certain areas, where right of way is available, as indicated by Government of Haryana, option of RRTS development along NH 1 could be undertaken.

4.5 Conclusions

4.5.1. Existing Railway Alignment

- The existing railway corridor passes through the outskirts of Delhi and the densely urbanized areas of Sonepat, Ganuar, Samalkha and Panipat. In between these settlements it passes through open countryside where manually operated level crossings exist at intersections with side roads.
- On the existing railway corridor, RRTS alignment can be developed on the eastern side to take advantage of the direction of existing track curvature. However, at Delhi conurbation significant works would be required to accommodate a new line adjacent to the existing, causing potential major disruption to the operation of the railway during construction and would require slewing of the existing track and/or demolition of adjacent property.
- Similarly ROW issues would arise at Sonepat, Ganuar and Panipat where the existing stations may have to be relocated to accommodate the new RRTS alignment.

- The rationale behind the RRTS is to provide a high-speed, non-stop service between Delhi and Panipat whereas the existing railway generally operates at lower line speeds. It would seem incongruous to combine these two alignments running at-grade as the RRTS corridor needs to be fully contained on both sides to prevent people and animal trespassing onto the tracks.
- Indian Railways may find it difficult to release operational railway land for the construction of the RRTS as they have future plans to expand and enhance their network between Delhi and Amritsar. This would entail further encroachment into the densely populated areas lying adjacent to the existing railway in the urban conurbations.

For these reasons the direct use of the existing railway corridor for the RRTS alignment cannot be recommended.

4.5.2. Existing NH 1 Alignment

- The NH-1 route runs to the east and generally parallel to the existing railway line from the Mukarba Chowk interchange northwards and connects Sonepat, Ganuar, Samalkha and Panipat with Delhi. The road generally comprises 6 lanes and some improvements (mainly grade separation at existing intersections) are currently under construction.
- To the south and east of Mukarba Chowk, NH-1 forms a connection with the Delhi Outer Ring Road and insufficient ROW is available to provide the RRTS along the existing road corridor up to Kashmiri Gate.
- Immediately north of Mukarba Chowk, NH-1 passes through densely urban development up to Krishna Nagar and fitting in an acceptable alignment for the RRTS would be very difficult without major demolition of property.
- At Sonepat the road passes directly through the conurbation at-grade, with priority junctions at the intersections with routes SH-14 and SH-20 at Bahalgarh and Murthal respectively. Dense development in close proximity to the highway limits availability of ROW for the RRTS alignment.
- At Ganuar, Samalkha and Panipat, NH-1 passes through these conurbations on varying sections of viaduct, with parallel connector roads providing access to the local network. There is insufficient ROW available to locate the RRTS alongside these major viaducts.
- In between these settlements the NH-1 corridor passes through open countryside and ROW for the RRTS would be available on one side of the road or the other. However, continuous ROW throughout the full highway corridor is unavailable without bypassing the settlements in some form and the tightness of curvature required for the RRTS on these sections would not meet required standards.
- The National Highway Authority has future plans to expand the NH-1 corridor from its present 6 lanes and may not like to release operational land for the construction of a parallel RRTS.

For these reasons the direct use of the existing national highway corridor for the RRTS alignment cannot be recommended for the entire alignment of RRTS.

However, in certain areas, where right of way through the green belt as indicated by Government of Haryana, is available, such option has been explored and incorporated in the proposed alignment route as explained in later chapters.

5. PROPOSED ALIGNMENT

5.1 Alignment Finalization Process

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

Travel Demand forecast	•Traffic survey and Stated Preference Survey •Inputs from Development Plans of various cities •Study alternative modes •Demand forecast for 2011 – 2041 including projections for modal shift
Detailed Analysis of Present Development along the corridor	Present and future development plans of the region developed by state government of Delhi and Haryana have been collected from relevant agencies for analysis so that the selected alignment caters to the future development plans of the region
Division of Corridor into Blocks and Identification of Alternative routes/ alignments for each Block	The entire corridor was divided into 9 blocks to understand and evaluate various sections. Alternative alignment paths in each block were analysed to be suitable for a RRTS alignment
Field Survey and analysis	The alternative alignments for each block has been analyzed by conducting detailed field surveys providing inputs on critical issues such as land acquisition, travel time, Cost, Ease of construction, Connectivity and TOD etc. for defining an alignment suitable for RRTS.
Study of Potential for Transit Oriented Development (TOD)	Identify TOD zone along RRTS alignment Revenue from TOD zones can be utilized as source of funding for the project.

5.2 Alignment Contours

The Delhi Sonepat Panipat RRTS alignment is proposed to start at Maharana Pratap Inter State Bus Terminus (referred to as Kasmere Gate Terminal in this report) in Delhi and ends at IOCL Panipat terminal in Haryana covering a total distance of 111.2 kms that includes a spur length of 10.6 kms at Gannaur Depot. The alignment consists of a mix of elevated (100.7 kms), underground (2.7 kms), and segregated At Grade (7.8 kms), sections across the length of the corridor. There are 12 stations and 2 depots proposed on the corridor.

The Delhi terminal of the RRTS corridor is proposed to be located underground at Kashmere Gate parallel to, and at the same level as that of new proposed phase III underground Delhi Metro station thus providing the commuters integration with Delhi Metro and Inter State Bus Terminus at Kashmere Gate. Exiting the Kashmere Gate terminus, the alignment remains underground to cross a park, residential areas and ring road and emerges on the east side of the ring road. Thereafter the alignment goes elevated and follows ring road to reach Mukarba Chowk station in Delhi and follows NH1 thereafter towards Narela Multi Modal Transit Centre. As a multimodal transit station is proposed in Delhi Master Plan at Narela, the alignment moves westward from NH1 to integrate with Narela MMTC and then again joins back NH1 alignment to proceed northwards to Haryana. In Haryana the alignment utilizes the greenbelt along the west side of NH1 with stops at Kundli, KMP interchange (Kundli Manesar Palwal Interchange), Rajeev Gandhi Education University, Murthal and Gannuar. At Gannaur, a spur of 10.6 km length has been proposed towards the west of the main alignment for RRTS depot and Gannaur Depot station that will serve the Transit Oriented Development Zone to be developed at Gannaur. Moving northwards from Gannuar city station, the elevated main alignment moves westward to cross the Indian Railway alignment to reach Samalkha station parallel to the Indian Railway station at Samalkha. From Samalkha the alignment moves northwards to reach Panipat City station and further terminates at Panipat IOCL terminal station. Depots are proposed at Panipat IOCL terminal and Gannaur. Along the alignment three Transit Oriented Zones are proposed at (1) IOCL Panipat, (2) Samalkha, and (3) Gannaur Depot.

Figure 5-1 RRTS Delhi Sonepat Panipat Alignment

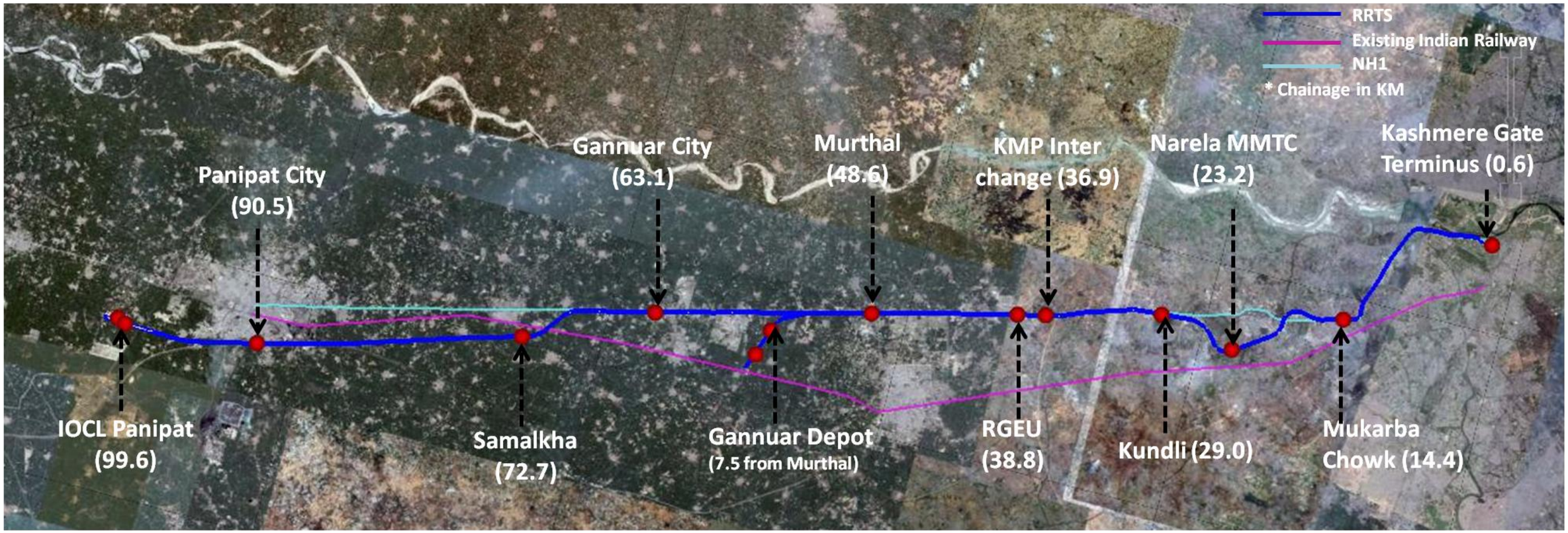
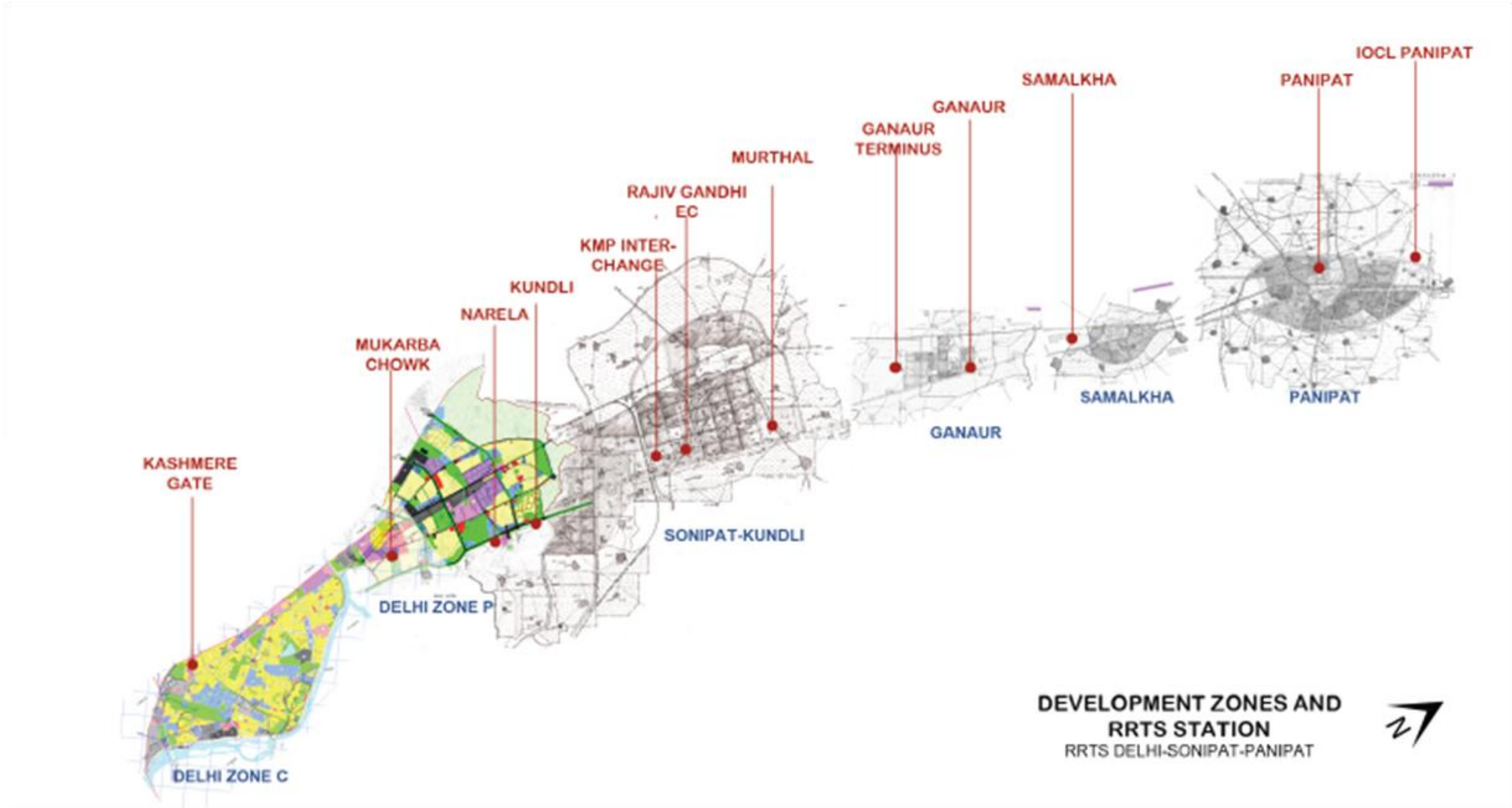


Figure 5-2 RRTS Delhi Sonepat Panipat stations and development zones



5.3 Stations Along the Alignment

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

Table 5-1 : Proposed Stations along the Corridor

Sr. No	Stations	Station location	Distance from Previous station (KM)	Total KM
1	Kashmere Gate Terminus	Underground		
2	Mukarba Chowk	Elevated	13.8	13.80
3	Narela MMTC	Elevated	8.8	22.60
4	Kundli Border	Elevated	5.8	28.40
5	KMP Expressway interchange	Elevated	7.9	36.30
6	Rajeev Gandhi Education City (Rai)	Elevated	1.9	38.20
7	Murthal (Sonepat)	Elevated	9.8	48.00
9	Gannaur (at NH1)*	Elevated	14.5	62.50
10	Samalkha	Elevated	9.6	72.10
11	Panipat City	Elevated	17.8	89.90
12	IOCL Panipat	At Grade	9.1	99.00
8	Gannaur Depot (along the spur)*	At Grade	7.5	106.5
	Additional Length of alignment			4.70
	Total Length			111.2

* distance from Murthal

The figure below describes the development zones in the cities along the alignment and shows the location of stations.

5.4 Transit Oriented Development Zones

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

5.4.1. Potential TOD sites

Three potential TOD sites have been in vicinity of IOCL Panipat, Samalkha and Gannaur Depot Stations. It is proposed that these areas be notified by the state Govt as the TOD zones allowing mix land use in the area. The figures below show a potential/ tentative areas at the three locations where a TOD zone can be developed. The exact areas can be refined subject to further discussions with respective authorities and agencies.

The potential areas for TOD have been identified based on availability of open land and by avoiding the inhabited areas and villages.

Figure 5-3:Potential area for TOD at IOCL Panipat

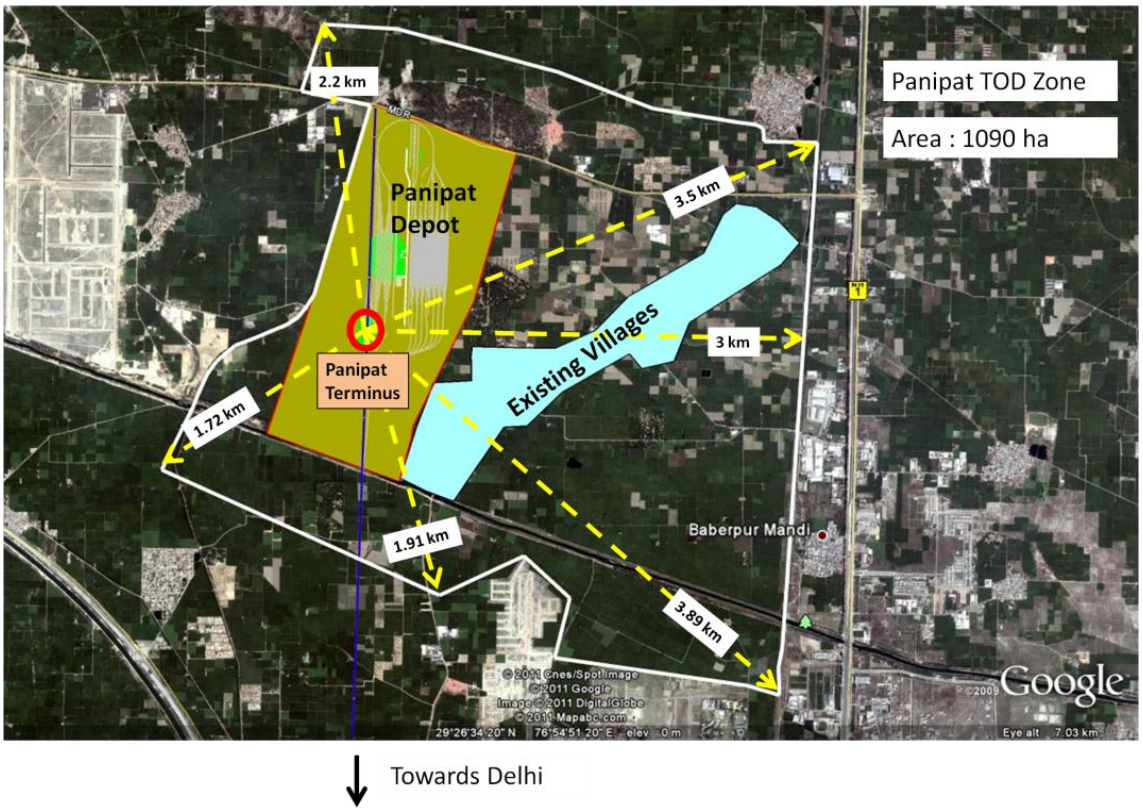


Figure 5-4: Potential area for TOD at Samalkha

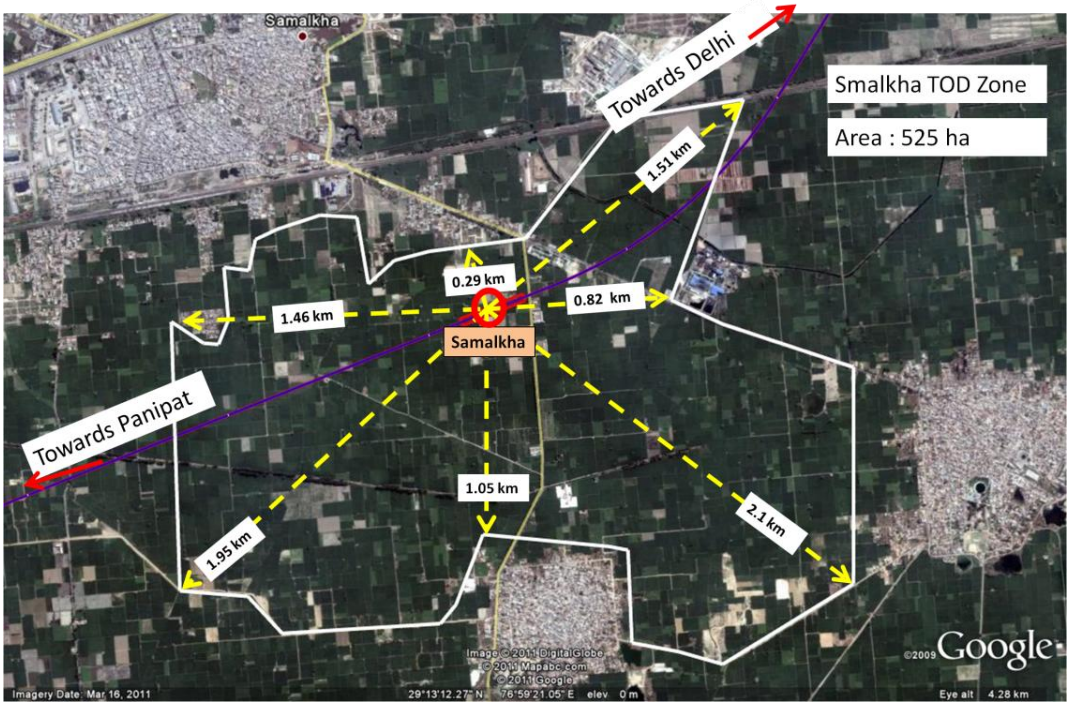
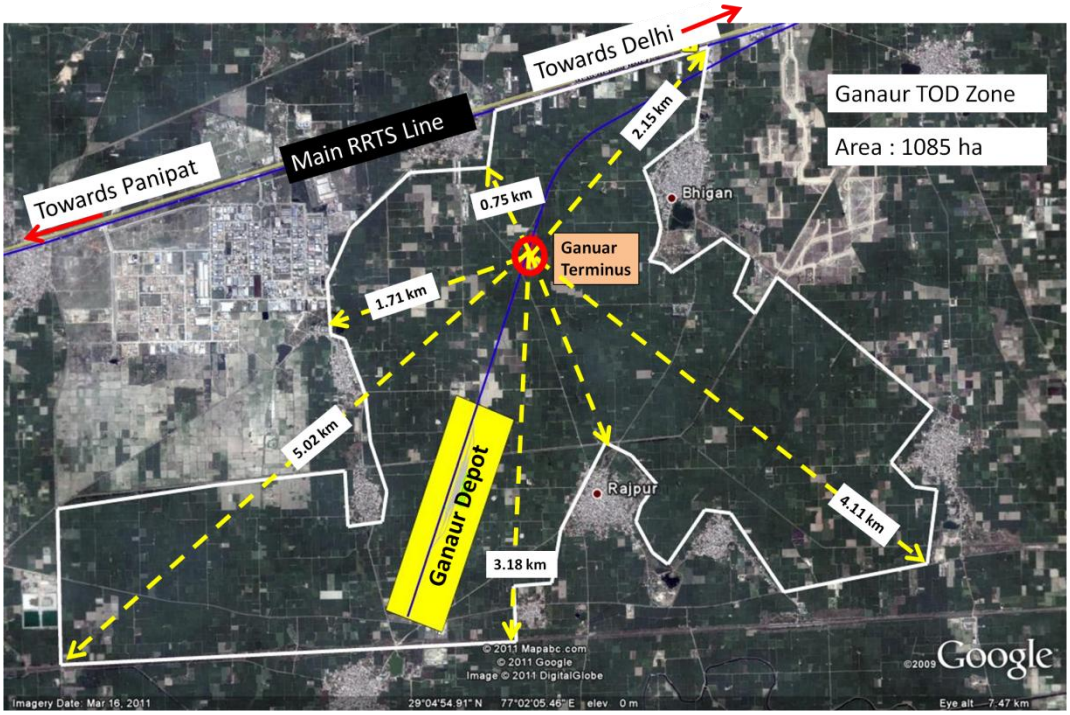


Figure 5-5: Potential area for TOD at Gannuar Depot



6. KEY INPUTS OF ENGINEERING AND OPERATIONS REPORT

6.1 Introduction

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

6.2 Rolling Stock Demand

Based on estimates of the demand made, the rolling stock requirement has been estimated for the years 2016, 2021, 2031, 2041 and subsequent years. The rolling stock in the intermediate years shall be based on actual demand achieved.

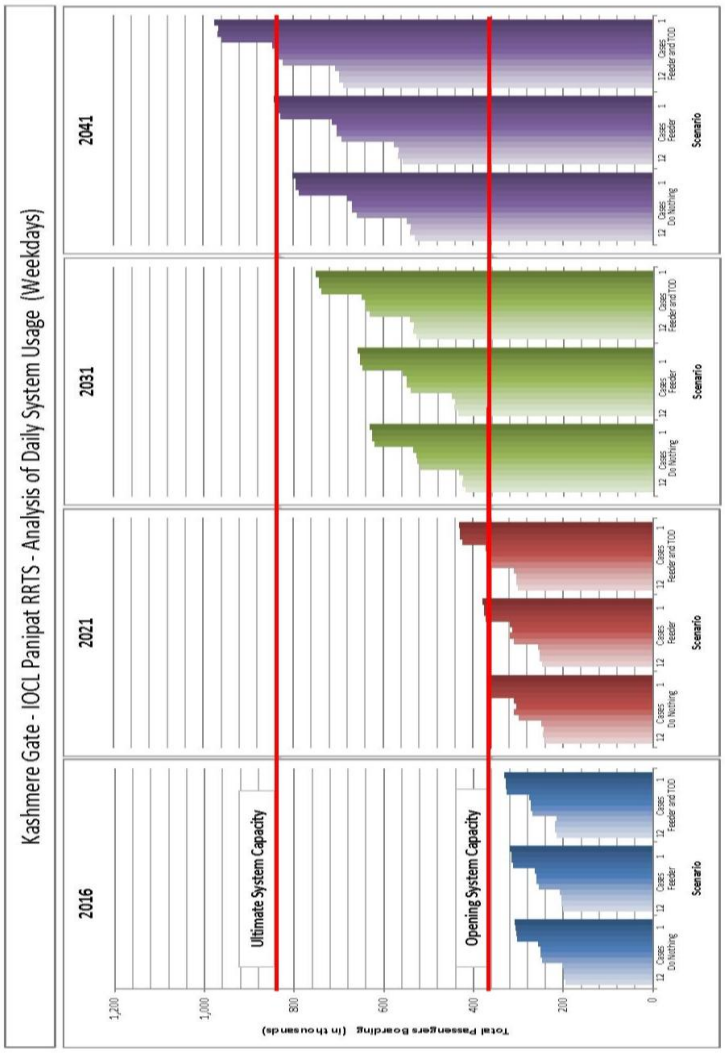


Figure 6-1 Analysis of detailed system usage

6.3 Rolling Stock Selection

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

- Operating headway of 3.5 minutes at Ultimate System Capacity (2041);
- Operating headway of 4.5 minutes at Opening System Capacity (2021);
- Cars of 3.7 metres external width;
- Three double doorways per bodyside of 1.5 metres nominal width;
- One luggage stack per driving car;
- Two luggage stacks per middle car;
- One wheelchair position per driving train;
- Seat pitch of 800 mm arranged airline-style. Alternatively, the seats could be arranged front/rear facing;
- Preferred maximum standing passenger density of 3 per square metre;
- No tables;
- No toilets;
- No catering facilities;
- No equipment cabinets within the saloons;
- No bicycle accommodation;
- No train crew accommodation (other than the drivers).

The 2 + 3 seating layout gives less luxurious accommodation than the 2 + 2 layout but it significantly reduces the number of cars and the length of the trains. However, with wider cars (3.7 metres) and the 2 + 3 seating layout the degree of luxury will still be relatively high and is expected to be comparable to cars such as BART SFO (the airline-style seating sections of the car).

System Capacity Timeline	Nominal Car Length, (metres)	Seating Arrang-ement	No. of Cars per Train	Length of Fixed-Formation Trains, (metres)	No. of Trains Required	No. of Cars Required
Ultimate System Capacity (2041)	24	2 + 3	9	220	44	396
Opening System Capacity (2021)	24	2 + 3	6	148	34	204

Table 6-1: Train and fleet sizes for 24 m long, 3.7 m wide cars with 2 + 3 seating layout and with standing passengers at 3 per square metre

The train fleet sizes include additional trains for hot-standby and maintenance purposes. For the Ultimate Capacity fleet, further trains are included for the necessary turn round procedures at the terminal stations.

Typical train configuration for 3 and 6 car train could be as follows:

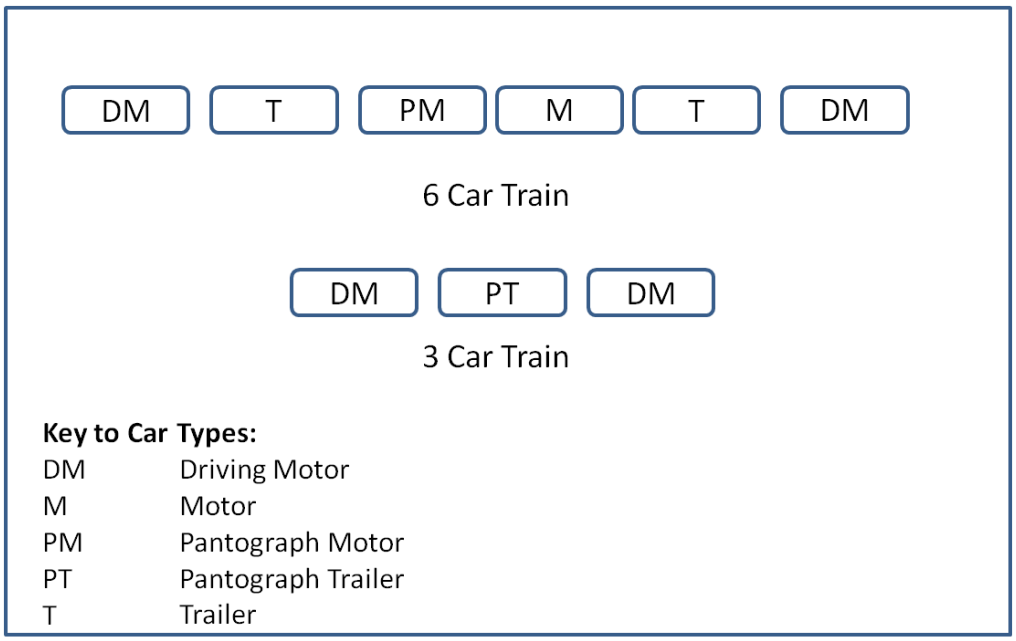


Figure 6-2 Possible train configurations

The options for the steps of fleet expansion have been analysed and are setout below :

Step	System Capacity Timeline	System Capacity PHPDT	Operating Headway, minutes	Number of Cars per Train	Number of Trains Required	Number of 3-car Units	Number of 6-car Units	Total Number of Cars Required
1	Opening (2016 to 2021)	15,028 (16,367*)	4.5	6	34	34	17	204
2	Increment (between 2021 to 2034)	22,737	4.5	9	34	46	28	306
3	Ultimate (2035 to 2043)	29,733**	3.5	9	44	56	38	396
4	Post 2041 (2044 to 2056)	39,831	3.5	12	44	96	40	528

* Increased standing density to 3.6/m^2 to achieve required capacity for 2021.

** Actual capacity exceeds 2041 required capacity.

Table 6-7: Train Fleet Expansion Steps

Figure below shows these expansion steps graphically.

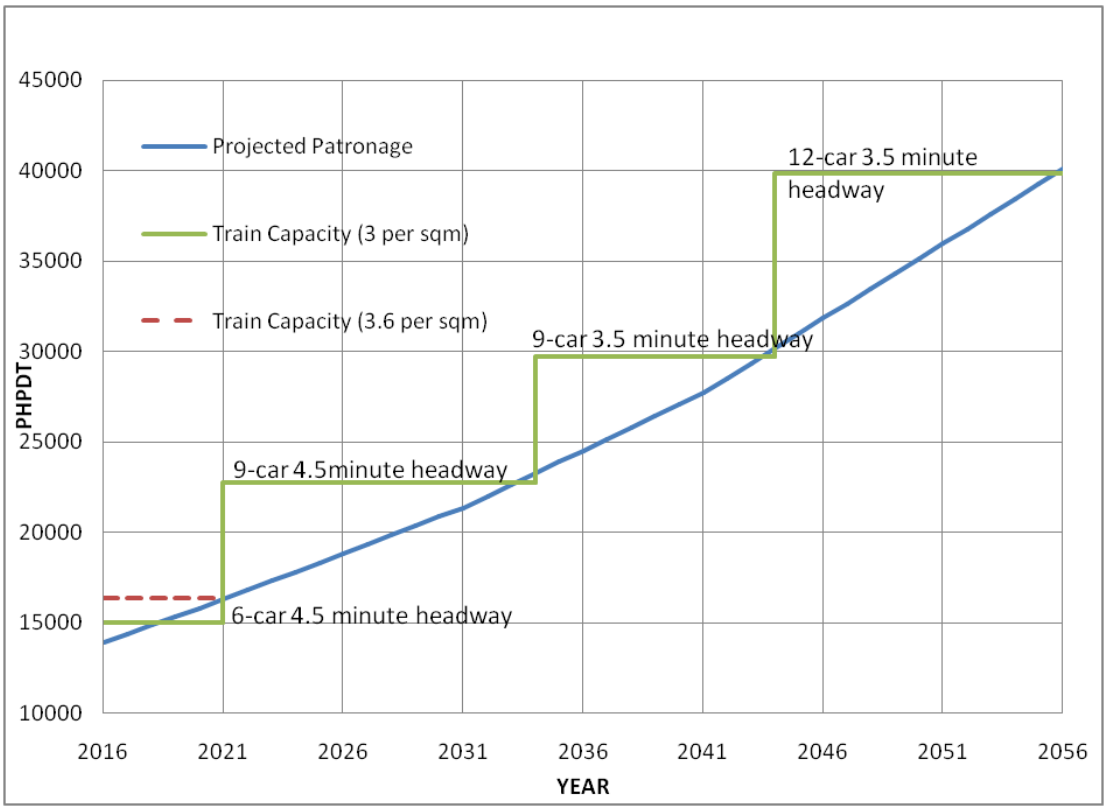


Figure 6-3 Planned fleet expansion profile

6.3.1. Train Requirements

For the envisaged rail system with optimised journey times, electric multiple-unit (EMU) trains are the most appropriate because the acceleration performance can be significantly better than locomotive-hauled trains.

6.3.2. Journey Time Simulations

Journey time analyses have been carried out using MTrain professional simulation software which has been assessed and verified on both UK and Australian national railway systems.

Figure 6-4 Gradient Profile and Line Speed Limits for stop-all-stations run from Kashmere Gate to IOCL Panipat

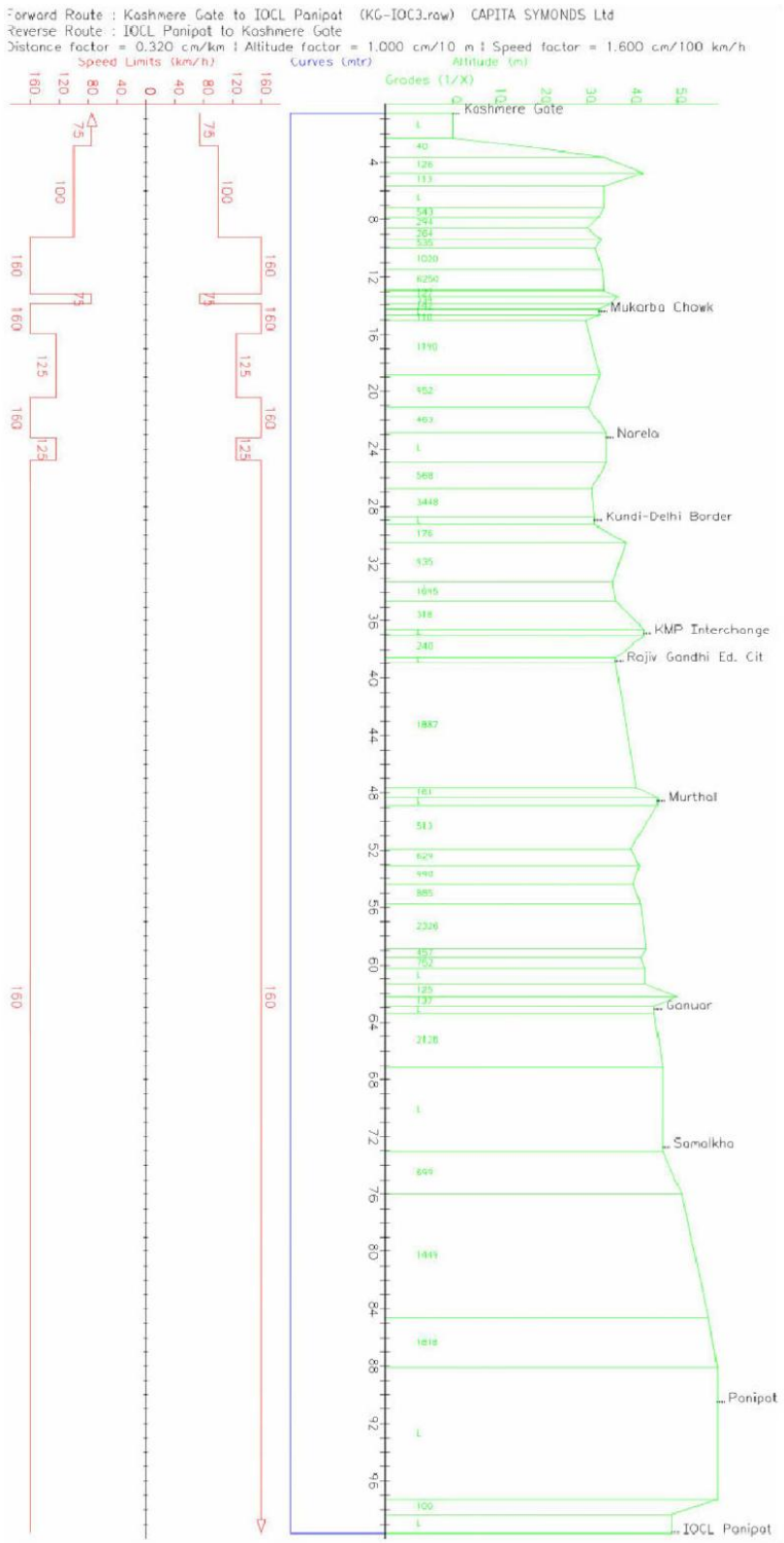
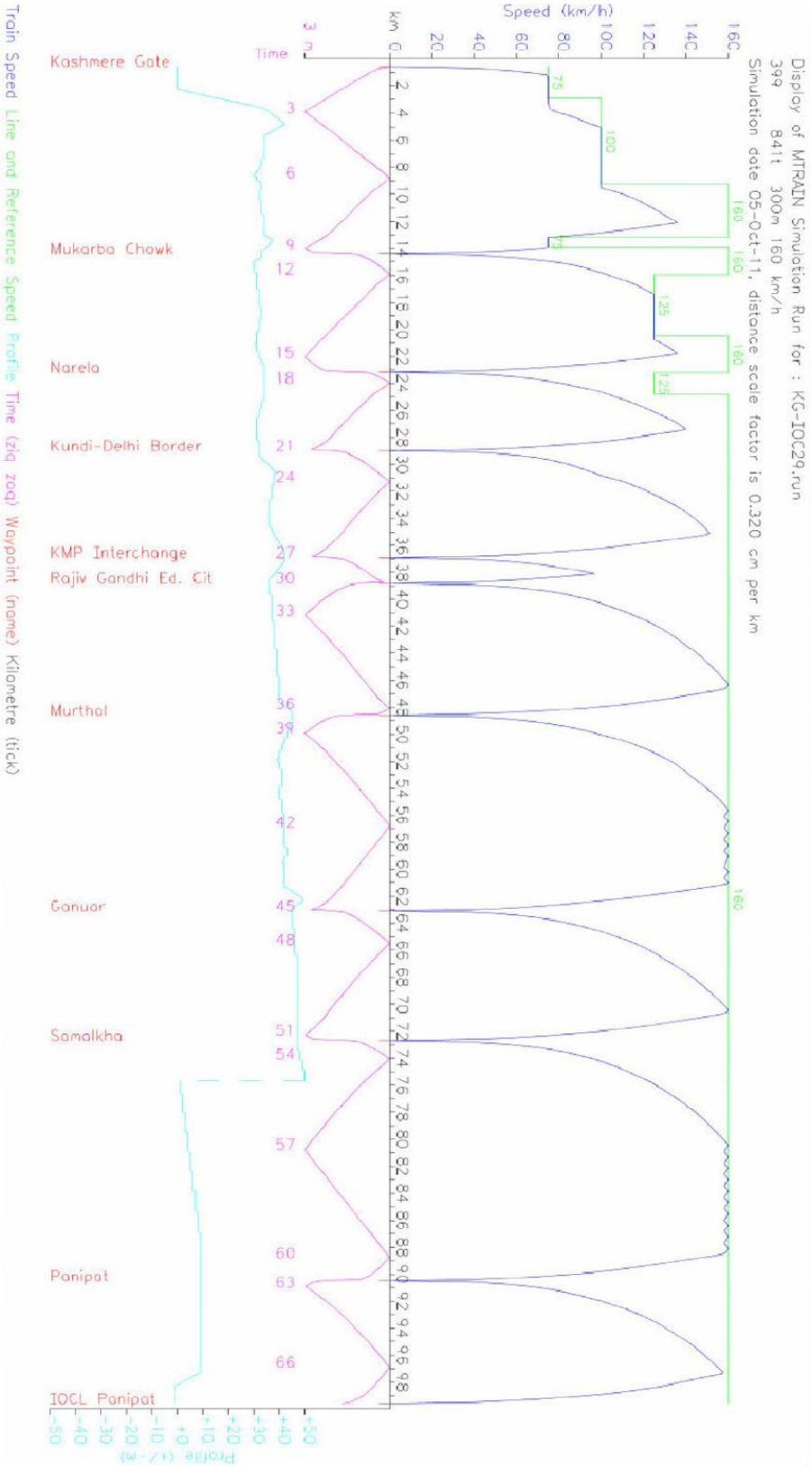


Figure 6-5 Speed profile for stop all stations run from Kashmere Gate to IOCL Panipat



6.3.3. Summary of Parameters of the Selected Trains

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

Parameter	At Opening System Capacity	At Ultimate System Capacity
Peak Hour System Capacity, PHPDT	16,281	27,683
Operational Headway, minutes	4.5	3.5
Required Train Passenger Capacity	1,252	1,628
Nominal Car Length, metres	24	24
Nominal Car Width, metres	3.7	3.7
Rail Gauge, mm	1,676	1,676
Seating Layout	2 + 3	2 + 3
Style of Seat Layout	Airline	Airline
Seat Pitch, mm	800	800
Density of Standing Passengers in Normal Service, per square metre	3	3
Number of Cars per Train	6	9
Train Length, metres (formed from 3-car units)	152	228
Train Stopping Accuracy at Stations, metres	10	10
Number of Doorways per Bodyside	3	3
Nominal Width of the Bodyside Doors, metres	1.5	1.5
Number of Luggage Stacks per Driving Car	1	1
Number of Luggage Stacks per Middle Car	2	2
Number of Wheelchair Positions per Driving Car	1	1
Number of Wheelchair Positions per Middle Car	0	0

Parameter	At Opening System Capacity	At Ultimate System Capacity
Toilets on the Trains	No	No
Tables on the Trains	No	No
Catering Facilities on the Trains	No	No
Bicycle accommodation on the Trains	No	No
Train Crew Accommodation on the Trains (other than the drivers)	No	No
Train Type	25 kV EMU	25 kV EMU
Train Configuration	Fixed formation of 3-car units and 6-car units	Fixed formation of 3-car units and 6-car units
Nominal Laden Car Weight (heaviest car), tonne	77	77
Extreme Car Weight, tonne	95	95
Train Power with 160 km/hr maximum speed, MW	1.90	3.00
Energy Consumption for Single Journey with 160 km/hr maximum speed, kWh	2,235	3,350
Regenerative Braking Required	Yes	Yes
Cab-end gangways with close-off doors	Yes	Yes
Passenger Saloons and Driving Cabs to be Air Conditioned	Yes	Yes
CCTV in the Trains	Yes	Yes
Maximum Train Speed, km/hr	160	160
Maximum Initial Train Acceleration, m/s^2	1.0	1.0
Initial Train Acceleration to be Independent of Train Weight	Yes	Yes
Maximum Braking Rate, m/s^2	1.0	1.0

Parameter	At Opening System Capacity	At Ultimate System Capacity
Average Service Braking Rate, m/s²	0.5	0.5
Stop-all-stations Journey Time from Kashmere Gate to Panipat IOCL, minutes	74	74
Stop-all-stations Journey Time from Kashmere Gate to Ganaur Terminus, minutes	41	41
Number of Trains to be Provisioned	34	44
Number of Cars to be Provisioned	204	396

Table 6-2: Summary of Parameters of the Selected Trains

6.3.4. Route Length

The report is based on a route length defined between Kashmere Gate and IOCL Panipat/Panipat Depot of 89km. However, following final agreement of the southern tunnelled alignment into Kashmere Gate and production of the topographic survey it is apparent that the route length is actually longer than this. The complete route length is made up as follows:

- Kashmere Gate to Panipat Depot 100.6 km
- Ganaur Junction to Ganaur Depot 10.6 km
- Total Route Length 111.2 km

A detailed listing of the proposed route alignment is given in Table below.

No.	Type	Length (m)	Radius (m)	Start Chainage (m)	End Chainage (m)	Proposed Linespeed (km/hr)	Cant for 160 km/hr	Cant Def for 160km/hr
Kashmere Gate to IOCL Panipat								
1	Line	412.469		560.943	973.413		Kashmere Gate	
2.1	T-C-T	69.000		973.413	1,042.413			
2.2	T-C-T	405.628	450.000	1,042.413	1,448.040	75	115	56
2.3	T-C-T	69.000		1,448.040	1,517.040			
3	Line	332.032		1,517.040	1,849.073	75		
4.1	T-C-T	72.000		1,849.073	1,921.073			
4.2	T-C-T	231.942	435.000	1,921.073	2,153.015	75	120	57
4.3	T-C-T	72.000		2,153.015	2,225.015			
5	Line	733.550		2,225.015	2,958.565	100		
6.1	T-C-T	36.000		2,958.565	2,994.565			
6.2	T-C-T	131.670	2,100.000	2,994.565	3,126.235	100	45	20
6.3	T-C-T	36.000		3,126.235	3,162.235			

No.	Type	Length (m)	Radius (m)	Start Chainage (m)	End Chainage (m)	Proposed Linespeed (km/hr)	Cant for 160 km/hr	Cant Def for 160km/hr
7	Line	697.686		3,162.235	3,859.921	100		
8.1	T-C-T	88.000		3,859.921	3,947.921			
8.2	T-C-T	143.781	850.000	3,947.921	4,091.702	100	110	51
8.3	T-C-T	88.000		4,091.702	4,179.702			
9	Line	108.465		4,179.702	4,288.167	100		
10.1	T-C-T	36.000		4,288.167	4,324.167			
10.2	T-C-T	197.710	2,100.000	4,324.167	4,521.877	100	45	20
10.3	T-C-T	36.000		4,521.877	4,557.877			
11	Line	462.495		4,557.877	5,020.372	100		
12.1	T-C-T	52.000		5,020.372	5,072.372			
12.2	T-C-T	175.962	1,350.000	5,072.372	5,248.334	100	65	37
12.3	T-C-T	52.000		5,248.334	5,300.334			
13	Line	157.852		5,300.334	5,458.186	100		
14.1	T-C-T	111.000		5,458.186	5,569.186			
14.2	T-C-T	1.837	600.000	5,569.186	5,571.023	100	150	79
14.3	T-C-T	100.000		5,571.023	5,671.023			
15	Line	168.324		5,671.023	5,839.347	100	≈Signature Bridge	
16.1	T-C-T	92.000		5,839.347	5,931.347			
16.2	T-C-T	824.913	802.000	5,931.347	6,756.260	100	115	56
16.3	T-C-T	92.000		6,756.260	6,848.260			
17	Line	1,960.556		6,848.260	8,808.816	100		
18.1	T-C-T	36.000		8,808.816	8,844.816			
18.2	T-C-T	245.533	2,100.000	8,844.816	9,090.349	160	45	20
18.3	T-C-T	36.000		9,090.349	9,126.349			
19	Line	1,331.609		9,126.349	10,457.958	160		
20.1	T-C-T	51.200		10,457.958	10,509.158			
20.2	T-C-T	704.684	6,000.000	10,509.158	11,213.843	160	40	19
20.3	T-C-T	51.200		11,213.843	11,265.043			
21	Line	827.552		11,265.043	12,092.595	160		
22.1	T-C-T	211.200		12,092.595	12,303.795			
22.2	T-C-T	346.392	1,200.000	12,303.795	12,650.186	160	165	128
22.3	T-C-T	211.200		12,650.186	12,861.386			
23	Line	326.368		12,861.386	13,187.754	160		
24.1	T-C-T	69.000		13,187.754	13,256.754			
24.2	T-C-T	546.640	450.000	13,256.754	13,803.394	75	115	56
24.3	T-C-T	69.000		13,803.394	13,872.394			
25	Line	2,069.571		13,872.394	15,941.964	160	≈Mukarba Chowk	
26.1	T-C-T	120.000		15,941.964	16,061.964			
26.2	T-C-T	426.490	1,200.000	16,061.964	16,488.454	125	120	59
26.3	T-C-T	120.000		16,488.454	16,608.454			
27	Line	778.258		16,608.454	17,386.712	125		

No.	Type	Length (m)	Radius (m)	Start Chainage (m)	End Chainage (m)	Proposed Linespeed (km/hr)	Cant for 160 km/hr	Cant Def for 160km/hr
28.1	T-C-T	150.000		17,386.712	17,536.712			
28.2	T-C-T	1,450.777	950.000	17,536.712	18,987.490	125	150	76
28.3	T-C-T	150.000		18,987.490	19,137.490			
29	Line	175.040		19,137.490	19,312.530	125		
30.1	T-C-T	130.000		19,312.530	19,442.530			
30.2	T-C-T	876.182	1,120.000	19,442.530	20,318.711	125	130	61
30.3	T-C-T	130.000		20,318.711	20,448.711			
31	Line	2,751.576		20,448.711	23,200.287	125	≈Narela	
32.1	T-C-T	150.000		23,200.287	23,350.287			
32.2	T-C-T	1,338.619	950.000	23,350.287	24,688.906	125	150	76
32.3	T-C-T	150.000		24,688.906	24,838.906			
33	Line	151.496		24,838.906	24,990.402	160		
34.1	T-C-T	140.800		24,990.402	25,131.202			
34.2	T-C-T	2,034.029	2,100.000	25,131.202	27,165.231	160	110	57
34.3	T-C-T	140.800		27,165.231	27,306.031			
35	Line	3,243.757		27,306.031	30,549.788	160	≈Kundli	
36.1	T-C-T	140.800		30,549.788	30,690.588			
36.2	T-C-T	341.337	2,100.000	30,690.588	31,031.926	160	110	57
36.3	T-C-T	140.800		31,031.926	31,172.726			
37	Line	2,963.069		31,172.726	34,135.795	160		
38.1	T-C-T	57.600		34,135.795	34,193.395			
38.2	T-C-T	476.064	5,000.000	34,193.395	34,669.459	160	45	25
38.3	T-C-T	57.600		34,669.459	34,727.059			
39	Line	840.290		34,727.059	35,567.350	160		
40.1	T-C-T	140.800		35,567.350	35,708.150			
40.2	T-C-T	234.838	2,100.000	35,708.150	35,942.988	160	110	57
40.3	T-C-T	140.800		35,942.988	36,083.788			
41	Line	1,193.717		36,083.788	37,277.505	160	≈KMP Interchange	
42.1	T-C-T-T-C-T	32.000		37,277.505	37,309.505			
42.2	T-C-T-T-C-T	464.391	10,000.000	37,309.505	37,773.895	160	25	10
42.3	T-C-T-T-C-T	32.000		37,773.895	37,805.895			
42.4	T-C-T-T-C-T	32.000		37,805.895	37,837.895			
42.5	T-C-T-T-C-T	359.878	10,000.000	37,837.895	38,197.773	160	25	10
42.6	T-C-T-T-C-T	223.000		38,197.773	38,420.773			
43	Line	4,334.944		38,420.773	42,755.717	160	≈Rajiv Gandhi EC	
44.1	T-C-T	30.000		42,755.717	42,785.717			
44.2	T-C-T	331.124	38,000.000	42,785.717	43,116.842	160	0	9
44.3	T-C-T	30.000		43,116.842	43,146.842			
45	Line	3,899.979		43,146.842	47,046.820	160		
46.1	T-C-T-T-C-T	57.600		47,046.820	47,104.420			
46.2	T-C-T-T-C-T	296.730	5,000.000	47,104.420	47,401.150	160	45	25

No.	Type	Length (m)	Radius (m)	Start Chainage (m)	End Chainage (m)	Proposed Linespeed (km/hr)	Cant for 160 km/hr	Cant Def for 160km/hr
46.3	T-C-T-T-C-T	57.600		47,401.150	47,458.750			
46.4	T-C-T-T-C-T	57.600		47,458.750	47,516.350			
46.5	T-C-T-T-C-T	217.764	5,000.000	47,516.350	47,734.114	160	45	25
46.6	T-C-T-T-C-T	223.000		47,734.114	47,957.114			
47	Line	1,234.377		47,957.114	49,191.491	160		≈Murthal
48.1	T-C-T-T-C-T	57.600		49,191.491	49,249.091			
48.2	T-C-T-T-C-T	286.410	5,000.000	49,249.091	49,535.501	160	45	25
48.3	T-C-T-T-C-T	57.600		49,535.501	49,593.101			
48.4	T-C-T-T-C-T	57.600		49,593.101	49,650.701			
48.5	T-C-T-T-C-T	209.443	5,000.000	49,650.701	49,860.144	160	45	25
48.6	T-C-T-T-C-T	219.000		49,860.144	50,079.144			
49	Line	1,518.870		50,079.144	51,598.013	160		
50.1	T-C	223.000		51,598.013	51,821.013			
50.2	T-C	2,422.079	200,000.000	51,821.013	54,243.092	160	0	2
50.3	T-C	0.000						
51	Line	1,487.136		54,243.092	55,730.228	160		
52.1	T-C-T-T-C-T	219.000		55,730.228	55,949.228			
52.2	T-C-T-T-C-T	298.690	5,000.000	55,949.228	56,247.919	160	45	25
52.3	T-C-T-T-C-T	57.600		56,247.919	56,305.519			
52.4	T-C-T-T-C-T	57.600		56,305.519	56,363.119			
52.5	T-C-T-T-C-T	340.212	5,000.000	56,363.119	56,703.331	160	45	25
52.6	T-C-T-T-C-T	219.000		56,703.331	56,922.331			
53	Line	2,093.332		56,922.331	59,015.662	160		
54.1	T-C-T	30.000		59,015.662	59,045.662			
54.2	T-C-T	301.160	15,000.000	59,045.662	59,346.822	160	15	8
54.3	T-C-T	30.000		59,346.822	59,376.822			
55	Line	258.662		59,376.822	59,635.484	160		
56.1	T-C-T	30.000		59,635.484	59,665.484			
56.2	T-C-T	217.563	15,000.000	59,665.484	59,883.047	160	15	8
56.3	T-C-T	30.000		59,883.047	59,913.047			
57	Line	565.237		59,913.047	60,478.284	160		
58.1	T-C-T	30.000		60,478.284	60,508.284			
58.2	T-C-T	608.457	20,000.000	60,508.284	61,116.741	160	0	18
58.3	T-C-T	30.000		61,116.741	61,146.741			
59	Line	3,570.215		61,146.741	64,716.956	160		≈Ganaur
60.1	T-C-T	57.600		64,716.956	64,774.556			
60.2	T-C-T	356.711	5,000.000	64,774.556	65,131.266	160	45	25
60.3	T-C-T	57.600		65,131.266	65,188.866			
61	Line	351.132		65,188.866	65,539.999	160		
62.1	T-C-T	57.600		65,539.999	65,597.599			
62.2	T-C-T	182.681	5,000.000	65,597.599	65,780.280	160	45	25

No.	Type	Length (m)	Radius (m)	Start Chainage (m)	End Chainage (m)	Proposed Linespeed (km/hr)	Cant for 160 km/hr	Cant Def for 160km/hr
62.3	T-C-T	57.600		65,780.280	65,837.880			
63	Line	707.389		65,837.880	66,545.269	160		
64.1	T-C-T	32.000		66,545.269	66,577.269			
64.2	T-C-T	375.457	10,000.000	66,577.269	66,952.726	160	25	10
64.3	T-C-T	32.000		66,952.726	66,984.726			
65	Line	530.480		66,984.726	67,515.206	160		
66.1	T-C-T	57.600		67,515.206	67,572.806			
66.2	T-C-T	361.891	5,000.000	67,572.806	67,934.697	160	45	25
66.3	T-C-T	57.600		67,934.697	67,992.297			
67	Line	189.895		67,992.297	68,182.192	160		
68.1	T-C-T	140.800		68,182.192	68,322.992			
68.2	T-C-T	1,239.386	2,100.000	68,322.992	69,562.378	160	110	57
68.3	T-C-T	140.800		69,562.378	69,703.178			
69	Line	1,230.213		69,703.178	70,933.391	160		
70.1	T-C-T	140.800		70,933.391	71,074.191			
70.2	T-C-T	1,216.600	2,100.000	71,074.191	72,290.791	160	110	57
70.3	T-C-T	140.800		72,290.791	72,431.591			
71	Line	4,073.543		72,431.591	76,505.134	160		≈Samalkha
72.1	T-C-T	32.000		76,505.134	76,537.134			
72.2	T-C-T	202.440	10,000.000	76,537.134	76,739.574	160	25	10
72.3	T-C-T	32.000		76,739.574	76,771.574			
73	Line	8,070.533		76,771.574	84,842.107	160		
74.1	T-C-T	32.000		84,842.107	84,874.107			
74.2	T-C-T	574.113	10,000.000	84,874.107	85,448.220	160	25	10
74.3	T-C-T	32.000		85,448.220	85,480.220			
75	Line	7,806.903		85,480.220	93,287.123	160		≈Panipat
76.1	T-C-T	32.000		93,287.123	93,319.123			
76.2	T-C-T	563.842	10,000.000	93,319.123	93,882.965	160	25	10
76.3	T-C-T	32.000		93,882.965	93,914.965			
77	Line	1,104.488		93,914.965	95,019.452	160		
78.1	T-C-T	57.600		95,019.452	95,077.052			
78.2	T-C-T	1,178.983	5,550.000	95,077.052	96,256.035	160	45	18
78.3	T-C-T	57.600		96,256.035	96,313.635			
79	Line	4,898.016		96,313.635	101,211.651	160		≈IOCL Panipat
Murthal to Ganaur Terminus								
1	Curve	23.017	185.000	0.000	23.017	60		
2	Line	69.585		23.017	92.602	75		
3	Curve	62.208	500.000	92.602	154.810	75	115	56
4	Line	382.062		154.810	536.872	75		≈Murthal Station
5	Curve	37.090	450.000	536.872	573.962	75	115	56

No.	Type	Length (m)	Radius (m)	Start Chainage (m)	End Chainage (m)	Proposed Linespeed (km/hr)	Cant for 160 km/hr	Cant Def for 160km/hr
6	Line	61.274		573.962	635.236	75		
7	Curve	37.090	450.000	635.236	672.326	75	115	56
8	Line	520.142		672.326	1,192.469	125		
9	Curve	34.454	1,000.000	1,192.469	1,226.922	125	130	61
10	Line	134.789		1,226.922	1,361.712	125		
11	Curve	34.454	1,000.000	1,361.712	1,396.165	125	130	61
12	Line	813.073		1,396.165	2,209.238	160		
13.1	T-C-T-T-C-T	57.600		2,209.238	2,266.838			
13.2	T-C-T-T-C-T	301.904	5,000.000	2,266.838	2,568.743	160	45	25
13.3	T-C-T-T-C-T	57.600		2,568.743	2,626.343			
13.4	T-C-T-T-C-T	57.600		2,626.343	2,683.943			
13.5	T-C-T-T-C-T	305.871	5,000.000	2,683.943	2,989.814	160	45	25
13.6	T-C-T-T-C-T	57.600		2,989.814	3,047.414			
14	Line	900.844		3,047.414	3,948.258	160		
15.1	T-C-T	57.600		3,948.258	4,005.858			
15.2	T-C-T	1,063.185	5,000.000	4,005.858	5,069.043	160	45	25
15.3	T-C-T	57.600		5,069.043	5,126.643			
16	Line	1,026.362		5,126.643	6,153.005	160		
17.1	T-C-T	120.000		6,153.005	6,273.005			
17.2	T-C-T	776.805	1,200.000	6,273.005	7,049.810	125	130	61
17.3	T-C-T	120.000		7,049.810	7,169.810			
18	Line	3,470.943		7,169.810	10,640.753	20	Ganaur Terminus Station and Depot	
T-C-T: Transition-Curve-Transition								

Table 6-3: Kashmere Gate to Panipat Route Details for Elevated Alignment

6.3.5. Track Gauge

Two track gauges are in common usage within India for fast railways, 1435mm (standard gauge) and 1676mm (Indian Broad gauge). Both gauges would be suitable for 160km/hr operational running or higher speeds. The 1435mm gauge is the most used gauge throughout the world; components are therefore less expensive and more readily available. However 1676mm gauge does have advantages in that the rolling stock can accommodate more passengers but this is countered by the fact that state-of-the art broad gauge rolling stock for 200km/hr railways will have to be specially designed and procurement will cost more and take longer. Inter running with other Broad Gauge railways will not be possible unless the signalling and control systems are similar.

For the RRTS: Delhi – Sonipat - Panipat the client has instructed that 1676mm Indian Broad Gauge will be used. This is acceptable due to estimated higher traffic volumes, shorter train lengths and bulk purchase for RRTS projects.

6.3.6. Track Structure

The railway will be subject to intensive train movements with little time for day to day maintenance. The track structure should therefore be designed to be long lasting with minimal maintenance. It should maintain a constant line and level commensurate with 200km/h running, passenger comfort levels and minimal noise and vibration.

Track will generally take one of two forms dependent on location. Within depots and stabling facilities the track will be ballasted using a traditional sleeper system. Sleepers may be formed of concrete, steel or timber but in the case of timber a separate baseplate will be required. These areas have low speed running and regular maintenance is possible. The main running lines will use a ballastless track structure. It is proposed to locate the rails on a resilient fastening system such as that manufactured by Pandrol, Clouth, Vossloh or other suitable company. The resilient fastening system will be fixed to concrete plinths incorporating derailment guard upstands.

6.3.7. Rails

It is envisaged that the rail type will be 60kg/m flat bottom. However, with the gentle curvature necessary for high speed lines it is not considered necessary to head harden the rail (although the railway operator/owner may decide to do this to increase rail life).

Rail will be continuously welded (CWR) throughout with de-stressing taking place if local conditions dictate. Long welded rail (LWR) and jointed track may be used in the depot/stabling areas.

Rails will be laid at an inclination of 1:20 with the rolling stock wheel profile machined for compatibility with the rail.

6.3.8. Cross Section Dimensions

The track cross section dimensions are built up as follows:-

Element	Dimension	Comment
Emergency walkway	1000mm 700mm	Generally At OLE mast positions
OLE structure	300mm	
Structure clearance	2135mm	To track centreline
Track interval	4290mm	Straight track
Track interval on curves	4460mm	Minimum 400mR

Table 6-4: Cross Section Dimensions

6.3.9. Vehicle Gauge

The proposed trains have an external body width of 3,700mm. To obtain the kinematic envelope a number of factors must be added, these include speed, suspension performance, vehicle build tolerance and track quality. The actual kinematic envelope will be determined after the design and construction of the vehicles.

For areas of the alignment where there are significant curves the swept envelope will be significantly different from the kinematic envelope since the swept envelope makes

allowances for end and centre throws. For the purposes of this report a maximum swept envelope width of 4,009mm has been assessed based on a 24m vehicle length and a minimum radius of 400m.

Indian Standards do not mention kinematic envelope but do specify 5,300mm between track centres. This is applicable to ballasted track on a mixed traffic route that will include freight and passenger vehicles with opening windows. Given the vehicle width of 3,700mm, this would give a static clearance between trains of 1,600mm. However, the railway is a new line, separated from the rest of the railway system and designed as a passenger only system using modern sealed rolling stock. Given that the proposed route is on viaduct it is appropriate that the proposed track interval is reviewed to minimise overall structure size and therefore provide an economically efficient design.

In the UK, guidance on the infrastructure is provided by the Health & Safety Inspectorate[1]. It provides guidance for line speeds up to 165km/hr. Given that the maximum design line speed for the railway is likely to be 160km/hr it is considered prudent to adopt the guidance until such time as technical workshops have been undertaken to look at the detailed issues involved and more detailed information is available from prospective train manufacturers. It suggests a passing clearance of 450mm between the swept envelopes of adjacent trains.

For a straight track, a static envelope of 3,700mm and a clearance of 450mm will give a minimum interval between the centreline of tracks of 4,150mm. This will increase once the detailed kinematic information is provided by the vehicle builders. For the purposes of this report a preliminary kinematic envelope of 3,840mm has been adopted giving an inter-track spacing of 4,290mm.

The track interval will need to be increased appropriately on curves. Based on the kinematic envelope of 3,840mm, increasing for centre and end throws and clearance of 450mm the inter-track spacing on the tightest curve on the system will be 4,460mm.

6.4 Signalling

6.4.1. Signalling System and the Timetable

From the information now available it transpires that the appropriate frequencies for ETCS Level 2 are unobtainable. Given this situation the most likely option would be to use ETCS Level 1 or an equivalent system such as CATC technology, as used on the Delhi Metro. The Delhi Metro operates at max speeds of 80km/hr, with averages of 30km/hr and at headways of 90 – 120 seconds. However, there are no apparent reasons to suppose that the CATC technology cannot be extended to this application. However it needs to be understood that with the increased line speeds of up to 160km/hr, there will be a consequent increase in the headways to a minimum of 210 seconds (3.5 minutes).

CATC provides similar Automatic Train Protection and Control as ETCS Level 1 but uses Audio Frequency Track Circuit overlays for system track to train communications.

[1] Railway Safety Principles and Guidance, Part 2, Section A, Guidance on the Infrastructure. Health & Safety Executive (Her Majesty's Railway Inspectorate)

The proposed signalling system should be reviewed at the time of bidding in favour of communication based system to see if an appropriate system has been implemented successfully somewhere in the world and has been running for a reasonable time.

The signalling system is based on discrete track sections to define the position of the tail of a train. The accuracy of this depends on the length of the section. Shorter sections increase the accuracy to which the tail of a train is known but increase the number required and hence increases the cost.

The system does not generally require visual line-side signals as the continuously up-dated speed profile is presented to the driver on an in-cab display. On the clearance of a section behind a train and subject to a system propagation time delay, the interlocking is up-dated and new data transmitted to the train to compute a new speed profile. Therefore the tail of a train is operating a fixed block function, with the system then keeping the cab of the following train as close to that point as possible yet at a safe distance. The ATP function enforces the correct speed/braking profile and provides the final defence in the event of a misjudgement by the driver. Appendix 4.1 gives pictorial details of a typical signalling system using this type of Control.

In normal operation therefore the signalling system should be transparent to the timetable and provide the safety back-stop when perturbations arise in operational service.

For reliable operation a margin of 30 to 60 seconds should also be taken in to consideration. There are measures that can increase this clearance time, but as noted previously, train characteristics and Line speeds are taken as fixed. The most efficient way identified for the project to achieve improved performance is through Shortening track sections in station areas – possible savings overall 10 secs as it provides a clearance time of 23 seconds. It is concluded that it is possible to operate a reliable 3.5 minute service.

6.4.2. Recovery Strategies

This is a line where operational difficulties due to equipment failure or more general operating events can have a serious effect on the service. Consideration should be given to generating such strategies either as a ‘soft’ solution using ATR and ATO and/or a ‘hardware’ solution by the use of additional equipment and lineside signals at strategic locations. Neither the technical details nor the costs have been investigated and most likely would form part of a study during the detailed design stage as the recovery strategy would necessarily be prepared by the D&B Contractor.

In the management of perturbations a number of factors can affect return to normal service. The adoption of statistical based real-time learning models based on a reasonably accurate dynamic model of the railway can improve performance on a continuous basis.

6.4.3. Rolling Stock Integration

Integration of the signalling equipment in to the rolling stock is only viable with vehicles specifically designed with the appropriate interfaces. Retro-fitting in practice has been shown to be technically difficult with high cost implications and uncertain performance.

6.4.4. Track Layouts

The proposed system provides a means of optimising timetable operation particularly on the running lines. Whilst it is technically feasible to control every train movement by automated signalling, in termini, consideration should be given to the use of additional

visual signals at strategic locations. These would improve efficiency in the movement of stock within the station limits.

Train protection would still be provided by the system. The installation would need to remain compatible with the signalling system.

6.4.5. Train Detection

As the primary method of train detection will be track circuits in the interests of safety an overlay dead-locking system for points should be provided.

6.5 Communications Systems

6.5.1. SCADA

The Supervisory Control and Data Acquisition System (SCADA) will monitor and/or control equipment of the System including the fare collection equipment, CCTV, public and non-public Emergency Telephones (ET). It will display the alarms and will be able to control some functions of this equipment. The Remote Terminal Units (RTU) will be located in stations, substations and at the Depot

The station equipment will consist of Remote Terminal Units (RTU's) located in the Electrical Equipment Rooms (EER), fed by the UPS. The RTU's contain Programmable Logic Controllers (PLC), terminal blocks, power supplies, relay contacts, digital inputs and outputs and equipment cabinets.

Preventive maintenance of the SCADA hardware consists of inspection with periodic checking and testing to keep the equipment in healthy condition. All RTUs and the central computers are equipped with diagnostic capabilities for performance testing. Due to the high reliability of the components used in the system, routine maintenance is not recommended. In the rare event that there is a failure of such components, it is sudden rather than gradual. Therefore, unnecessary handling can only encourage failures.

6.5.2. Fibre Optic Communication System

The Fibre Optic Communication System (FOCS) will provide audio and data circuits between the depot and the passenger stations. Communications will be achieved by use of a redundant fibre optic ring to interconnect Network Elements (NE). The Network Management Subsystem (NMS) will use a graphical user interface to centrally manage and control the network. Status alarms, link performance data, and configuration information from remote sites will be available. Maintenance personnel will be able to use the NMS to diagnose major faults from any NE.

The maintenance operation is a real time fault detection system of transmission equipment; complete with alarms, graphic displays and diagnostics for determining specific components failure and for routine checks of the FOCS.

6.5.3. Emergency Telephones

Emergency telephones will be located throughout all passenger stations to provide immediate access to the Operations Control Centre (OCC). A computer facility will routinely poll each emergency telephone to perform diagnostics and confirm functionality. Preventive maintenance consists of a visual check of the telephone case, cord, and handset; followed by a test confirming swift response and good speech quality with the OCC.

6.5.4. Closed Circuit Television

The Closed Circuit Television (CCTV) system provides visual monitoring of selected areas. All station cameras are transmitted to the OCC via Ethernet over the FOCS. Maintenance is primarily referred to as users' maintenance. The determining factor is video quality i.e. meeting the user's requirements aided by adjusting the monitor's contrast and brightness controls. Video quality is confirmed by the users' during the performance of their normal daily duties.

6.5.5. Passenger Information Display System

The Passenger Information Display System (PID) provides centralized and station control of dynamic displays throughout the passenger stations. Preventive maintenance includes cleaning and inspection. Maintenance and repair of this system is by the replacement of LRUs.

6.5.6. Public Address System

The Public Address system (PAS) system provides coverage, for pre-recorded and other announcements, in passenger stations and passenger concourses. Preventive maintenance includes cleaning and inspection. Sound quality is confirmed by the Station Attendant during the performance of their normal daily duties. All deficiencies are reported to the Operations Control Centre.

6.5.7. Fare Collection System

The fare collection system is a key interface between a transit agency and its passengers. It directly affects the way in which passengers experience and perceive the transit agency and its services. In general, the transit passenger expects a fare system that:

- Is fast, easy to understand and use, with reliable fare transactions;
- Offers payment options that suit their particular travel needs (frequent, infrequent, weekly, daily, short-distance, etc);
- Allows easy transfers between modes and different transit providers; and
- Provides easy access to fare media.

Automatic fare collection system (AFCS) meets the requirements of an efficient, reliable and convenient ticketing system for a transit agency. In an AFCS, the fare is paid through an electronic payment media like a smart card or token. In case of gated systems (or closed systems), the passenger taps the payment media on a smart card reader at entry and exit gates and the appropriate fare is automatically debited from the smart card. In case of open system, the passenger taps the payment media on-board the vehicles.

The major components of the AFCS for RRTS will be as follows:

(i) Smart Card and Tokens – the payment media will be contactless smart cards and tokens. The smart cards will be anonymous cards and will be issued against a refundable deposit. The tokens will be issued for single journey and will be collected back at exit gates.

(ii) Ticket Office Machines (TOM) – The Ticket Office Machines will be used for issuing smart cards and tokens and topping-up of smart cards. The TOMs will be installed at all stations of the RRTS.

(i) Entry/exit Gates with smart card reader – The stations will have unpaid and paid areas, segregated by automated gates. The gates will have smart card readers built-in for validating and debiting fare from smart cards and tokens. On presenting a valid smart card/token, the gate will open allowing a single passenger to pass through. The passengers with tokens will have to insert token in a slot on the gate at the time of exit.

(ii) Station Computer – The station computer will be a server class machine, which shall manage all the gates on the local area network. The Station Computer shall communicate with the Central System over a secured link.

(iii) Central System – The Central System will be a key component of the AFC System, comprising of high-end servers (application servers, database servers,

communication servers, web servers, etc.), storage, printers, UPS, networking, connectivity, power backup, third party software (RDBMS, operating system, firewall, antivirus software, etc.) and AFCS backend application software. Sufficient redundancy will be built in at various levels to ensure high uptime of the system. The AFCS backend application software will be a highly scalable, reliable, secure and flexible system.

(iv) Customer Care/Helpdesk system – The AFCS will include a Customer Care/Helpdesk which will facilitate answering customers' queries and resolving their grievances through various modes including IVRS, website, e-mail, etc.

6.6 Selection of Structural Form

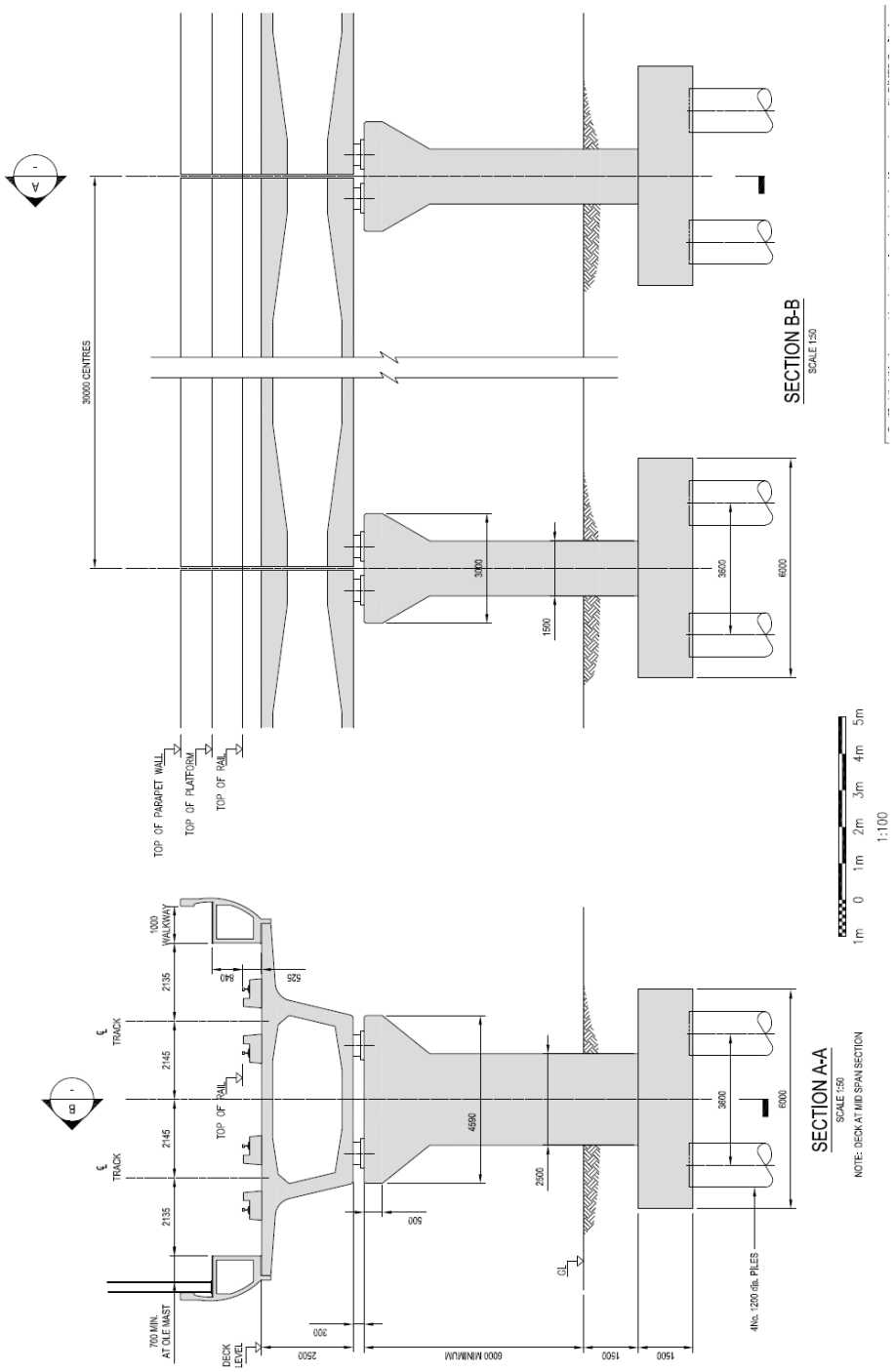
The proposed railway between Delhi and Panipat will be 100.6km long, excluding the branch to Ganaur; nearly all to be constructed on viaduct. Based on the geotechnical information available during the feasibility study, a pier spacing of 30m was chosen as a compromise between span length and possible substructure complexity. The design span of 28.8m is at the lower end for economic box girder construction.

Assuming the railway length of 100.6 km and a span of 30m then a guide to the total number of spans is:- 100.6 x 1000 / 30 = 3353 spans

The standard viaduct section will be formed from a precast post-tensioned concrete box girder, simply supported on single piers which are founded either on bedrock or a piled slab. The deck will carry the double track railway and will be completed by pre-cast parapets which will also form a continuous emergency walkway on both sides of the structure. Single track viaducts using similar features to the standard viaduct will be required on link lines and at stations with island platforms.

Comparison with the Taiwan High Speed Rail project with 157km of continuous viaduct shows that the viaduct is made up of 35m long precast post-tensioned concrete box girders simply supported on single columns. The deck units have free sliding mechanical pot bearings at each corner. Shear keys at either end of the span provide transverse restraint with one end fixed longitudinally.

Figure 6-6 Precast Post Tensioned Box Girder



The end rotation of a bridge deck due to the passage of trains is also an important factor for determining satisfactory rail / structure interaction. Preliminary calculations suggest that rotations should be acceptable for the 2,500 mm thick deck under full Load Model 71 loading.

Each substructure for the standard double track viaduct will be formed from a single reinforced concrete pier rising from a foundation slab supported on piles or bedrock according to the soil conditions. The feasibility study considered a minimum height of 6m from ground level to viaduct soffit with 1.5m cover to the ground slab. Preliminary

calculations suggest that a pier 2.5m wide by 1.5m thick will be sufficient to resist the horizontal loads imposed from the railway or by seismic loads. The bearings will be placed on a cross-head which will be dimensioned so that bearing replacement can be carried out without additional temporary works.

Clearance to the deck soffit will be a minimum of 6m. At pier positions the cross-head will reduce this to around 4.5m. The appearance of the pier and cross-head will harmonise with the deck and parapets to give an aesthetically pleasing finish.

6.6.1. The Tunnel and Portals

For the first 2.5km length of the route out of Delhi is proposed to run underground, starting in a new station box near the existing DMRC Kashmere Gate station. This solution has been proposed as a measure to overcome the problems of bringing the track above ground through heavily congested area around Kashmere gate and also to enable the RRTS to link in with the current and proposed Delhi metro located approximately 20m below ground level at Kashmere Gate.

6.6.2. Tunnel Geometry

Currently it is proposed that the RRTS tracks will run in twin bore tunnels with an external diameter of 7.70m.

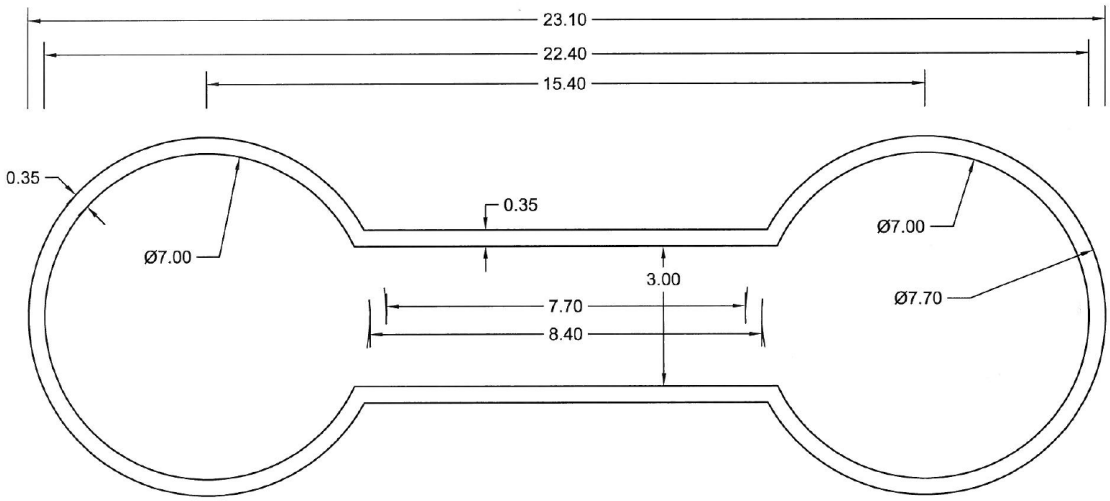


Figure 6-7 Schematic of the Twin Bore Tunnel Section

6.6.3. Previous Tunnelling in New Delhi

The following information is based on a study by Izumi. C and Lovelock. C et al[2]. which details the experience gained from the tunnelling works undertaken to facilitate the Delhi Metro Phase-II project.

Construction of the Delhi Metro Phase-II commenced in 2006 with the project comprising 94km of viaduct section and 30km of underground works. A total of 14 EPB TBMs have been used to complete the tunnelling works.

The tunnels were formed in southern New Delhi area, approximately 7km south of Kashmere Gate station. The ground conditions encountered consisted of predominately the Delhi Silts, specifically dense sandy silts and silty sands. The groundwater level in the area typically ranged from 10m to 35m bgl. In certain locations, the tunnel drives encountered localised outcrops of quartzite, in various stages of decomposition.

Tunnel progress was generally good with an average daily progress rate of 8.0m and a maximum daily progress of 34m. The TBMs were fitted with cutting discs on the periphery of the cutter head to assist with breaking through diaphragm walls at the portal areas and to cope with the localised outcrops of weathered quartzite.

Ground settlements were recorded in the range of 5mm to 20mm and volume loss was generally 0.3 – 0.8%. The main reason for the low settlement values was predominately down to the proper management of the TBMs operational procedures including face pressures and mucking rates.

6.7 Train operational Plan

The number of passengers per day (Monday to Friday) is taken for 2021, which includes for TOD and feeder services. From the *Travel Demand Forecast Study* the

[2] Izumi.C, Lovelock.C, Tyagi.J and Kumar Gupta.S (2009). A Review of Delhi Metro Tunnel Construction with 14 EPB Shield TBMS. WTC 2009.

likely passenger numbers on an hourly basis were calculated for the existing four stations which will have a station on the high speed line: Panipat, Samalkha, Ganaur and Narela.

Timetable for selected options is provided in the Appendix 7.1.

6.7.1. Selected Option : All Stations Services to Panipat

For this option it was proposed that the daytime service would be a ten minute interval service between IOCL Panipat and Kashmere Gate and a ten minute interval service between Ganaur Terminus and Kashmere Gate. This would then provide a five minute interval service between Murthal and Kashmere Gate.

Subsequently and in order to provide the required passenger capacity, the service headway was reduced to 4.5 minutes and hence this option would be a nine minute interval service between IOCL Panipat and Kashmere Gate and a nine minute interval service between Ganaur Terminus and Kashmere Gate. Such a service will take 74 minutes between IOCL Panipat and Kashmere Gate, could be accommodated on a double track railway, and will require 29 train sets to operate. The total fleet will be 34 trains including standby trains and maintenance requirements.

6.7.2. Number of Train Sets

The basic “all-stations” 2021 timetable (Option A) requires 29 train sets to cover all services. Additional trains must be allowed for “hot standby” and maintenance purposes, necessitating a requirement for 34 train sets (all-stations service). The actual configuration of the trains will be decided in the subsequent phases of the project and will depend on actual service requirements. For the purposes of this report it is assumed that trains are identical and are a single set of cars (ie there are no internal cabs within the configuration to allow trains to be subdivided).

6.7.3. Provision for Engineering Work

It should be noted that provision will need to be made for engineering work to be carried out. Generally, there are three options:

- replace trains with buses/coaches when the line needs to be closed for engineering work.
- run services over one line of the railway allowing engineering work to be carried out on the other (bidirectional working);
- do not run any services at night;

Decisions regarding the type of night service provided will depend on further detailed review of safe access to the viaduct for maintenance of the railway through hazard studies during the detailed design stage of the project. The initial proposal is that no services run during the night so that access can be provided for maintenance and engineering staff.

6.7.4. Notes on the Timetable

At some stations, such as Murthal, separate arrival and departure times are shown. Where this is not the case and just one time is shown, this is the departure time. In such cases the station dwell time (i.e. the time the train is stationary at the station platform) is 1 minute, except at Kundli, Rajiv Gandhi EC and Samalkha stations, where the dwell time is reduced to 30 seconds due to the limited patronage.

It will be noted that a grade separated junction is required at Murthal to avoid conflict between northbound Kashmere Gate to IOCL Panipat services and southbound Ganaur Terminus to Kashmere Gate services.

6.7.5. Service Recovery Plan / Emergency Plan

It is essential that service recovery and emergency plans are developed during the detailed design stage to address recovery of the service level after perturbations have disrupted the service.

6.8 Users Safety

During normal operation this safety is addressed by keeping passengers within defined areas within the station building or on the trains themselves. As the System is on a viaduct the rails will be securely fixed to the structure and it will be possible to minimise the platform edge gap and the difference in levels between the train and the platform to minimise the risk to passengers. Access to the viaduct is not available to passengers except in emergency scenarios. The use of CCTV and other security systems will assist in providing a safe environment for passengers.

During degraded operations this is addressed in the same manner as during normal operations although additional information may need to be provided to keep passengers informed of events, prevent them from entering stations, or directing them from the stations as required.

During emergency scenarios the emergency plan would be used to clear the system of passengers and evacuate them to a place of safety. One scenario the emergency plan will need to consider is the evacuation of passengers from a failed train on the viaduct. Evacuation routes shall be considered at the detailed engineering stage to ensure suitable and sufficient provision is included.

6.8.1. Workers

During normal operations the safety of staff and workers is governed by the security and maintenance protocols that prevent access to dangerous areas of the system until it is safe to do so. Staff and maintenance workers will need to be trained in the safe operation and maintenance of the System with access to specific areas allowed only to those that are suitably qualified. Although Indian Railways have existing safety systems, an enhanced qualification will need to be developed to cover the railway due to the limited access available and line specific technology.

The railway operations plan will need to include protocols for various scenarios of degraded and emergency operation so that all staff and maintenance workers have a clear understanding of options available to them for operating the System in a safe and effective manner.

A safe means of access to all areas of the System shall be provided for all staff and maintenance workers.

6.8.2. Non-Users

The safety of non-users adjacent to the railway will need to be considered during the design, construction, operation and maintenance of the System. The design will need to include consideration of noise and vibration impacts during the construction, operation and maintenance of the System.

In order to maintain the safety and integrity of the System it may be necessary to provide alternative access for people affected by the system. The design will need to

consider any alterations necessary to maintain highway access etc to areas adjacent to the railway.

Process will need to be reviewed as part of the design and construction process to ensure that the railway systems do not affect adjacent systems and that the adjacent systems do not affect the railway systems.

6.8.3. Plant and Machinery

A safe means of access to all plant and machinery shall be provided for all staff and maintenance workers.

The detailed design consultant will ensure that plant and machinery is adequately sized to perform its function correctly and that moving clearances are adequate to prevent collisions occurring.

Maintenance protocols shall be developed as part of the detailed maintenance plan to ensure that adequate systems are in place for the safe operation and maintenance of the System.

6.8.4. Emergency Planning

The requirement for tie-ups with Police, Hospitals, Voluntary organizations, Fire-fighting stations/organizations etc. en route will need to be developed so as to obviate the need for permanent staff for the purpose. The details of the interface with such organisations will be developed during the operational planning stage as part of the service recovery and emergency plan. It will be necessary for the design, build and operating contractors to include for developing these requirements.

6.8.5. Scenarios

Typical scenarios which the above plans should address are:

- timetable delays caused by minor perturbations.
- Passenger taken sick on train
- failed train at station.
- failed train on viaduct
- train on fire at station
- train on fire on viaduct
- highway vehicle collision with viaduct/pier
- building or vehicle on fire near or under a viaduct or pier
- signalling failure
- power failure

6.8.6. Train Evacuation Plan

An outline of a typical train evacuation plan is as follows:

1. The safest location for passengers in the event of an emergency is either on the train or in a station. Accordingly subject to the nature of the emergency passengers will always be advised by the train driver/conductor or operations control to remain in that place of safety. An emergency on board the train such as passenger sickness should be reported to the driver or conductor who will radio

ahead to the emergency services to meet the train at the next station where aid can be given.

2. If a train fails but is able to be moved then it should be coupled to the following train and shunted to the nearest station where passengers will detrain and wait to continue their journey. The failed vehicle will be taken to the nearest depot for inspection/repair.
3. If a train fails but cannot be moved due to brakes locking on for example, the following train shall temporarily couple to the failed train and the passengers will transfer to the following train via the trackside walkway on the viaduct. Bidirectional working will be initiated to allow services to by-pass the failure and passengers from the failed train will be taken to the nearest station.
4. If an emergency occurs which will require removal of passengers from the train, for example fire on board, then the passengers in the alight carriage will be asked to proceed to the trackside using the emergency detraining instructions which will be posted by each door. The passengers will move from the train to the walkway at the side of the viaduct parapet and walk calmly to the nearest exit staircase. Viaduct exit staircases will be provided at 2 – 3 km intervals. At no time will passengers be encouraged to walk along the track itself.

6.9 Maintenance Plans

The core railway system maintenance tasks shall cover the following :

- trains
- workshop equipment including maintenance of lineside equipment
- signalling/communication systems
- traction power supply and distribution including OLE system
- fare collection system, and
- permanent way including tracks, switches, sleepers, ballast
- This is followed by a description of the non-core railway system maintenance tasks covering the following:
- maintenance of safety-related equipment in stations
- facilities/infrastructure maintenance
- civil works maintenance
- cleaning services

Level 1 Maintenance

This level of maintenance is preventive in nature and consists of regularly planned inspections performed at various time intervals. During these inspections, in addition to the basic and routine servicing of equipment, tasks are performed to check and verify functions and operating characteristics to ensure maximum performance during full service operation. On board data collection and portable diagnostic tools will be required to collect performance data and provide a thorough diagnosis of the systems and support trends and root cause failure analysis.

Level 2 Maintenance

This level of maintenance is corrective or emergency in nature and can be carried out at site in the case of fixed installations or at the maintenance depot in the case of the trainsets. This often involves rapid interventions performed by maintenance staff to ensure minimum disruption and downtime to service operations.

Level 3 Maintenance

Level 3 Maintenance is the repair and scheduled general overhauls of equipment. Provisions are made in the workshop design and equipment supply to carry out repairs as required to most system elements. While some of this work will be performed in-house, many tasks will be subcontracted offsite to suppliers or specialised workshops.

6.9.1. General Duration per Main System Components

The life span (design life) and residual life of major subsystems are presented in the following table. Achievement of the residual life will be largely dependent on implementation of the regular (short term) preventive maintenance schedules for the Core and non-Core railway subsystems, as well as the long term preventive maintenance tasks discussed in this section.

To ensure that the life span and residual life is achieved, all Core and non-Core Railway System equipment and civil infrastructures will be serviced at long term intervals as well. Most of these intervals and associated tasks are repetitive in nature. These types of preventive maintenance tasks are usually referred to as either overhauls, replacements or renewals.

Asset Group	Design Life Required (Years)	Major Upgrade/ Refurbish needed
Rolling stock	25-30	15
Permanent Way	30	15
OLE Contact Wire	15-20	Partial
OLE Support Structures	40	No
Sub Station Equipment	40	No
Signalling System	25	No
Communications Equipment	10-15	Yes
CCTV	15	Yes
Fare Collection	20	No
Escalators, lifts, etc.	20	No
Depot Equipment	25	No
Cabling	30	No
Earthworks	>50	No
Structures/ Bridges	>50	No
Roads and Paving	20	No
Park and Ride Infrastructure	20	Yes
Park and Ride Equipment	10	Yes
Buildings	40	No
Station Structures	40	No

Asset Group	Design Life Required (Years)	Major Upgrade/ Refurbish needed
Station E&M Systems	25	No
Fire Detection and Suppression Systems	25	No

Table 6-5: Asset Design Life

6.10 Power

The RRTS: Delhi – Sonipat – Panipat railway will be a high power user. Supplies will be required for both traction and non traction systems supplied at high voltage.

6.10.1. Non-Traction Power

Non-traction power is required for both railway infrastructure and for commercial or retail opportunities located at stations. Due to the need to maintain the rail system resilience, it is recommended that the rail power infrastructure is provided separately from the commercial supplies wherever possible. This power is excluding the power required for commercial areas.

Location	Non traction Power (kVA)	Commercial Power (kVA)
Depot (Panipat)	973/1,720**	0
IOCL Panipat	490*	375
Panipat	490*	375
Samalkha	490*	375
Ganaur	490*	375
Ganaur Terminus	490*	375
Ganaur Depot	567	-
Murthal	490*	375
Rajiv Gandhi Educational City	490*	375
KMP Interchange	490*	375
Kundli	490*	375
Narela	490*	375
Mukarba Chowk	490*	375
Kashmere Gate	725	440
System losses 0.85 PF & 10% uplift allowance	8,420	457
Typical System Load	9,263	5,681
*Based on typical station layout. **Panipat Depot load 2035 onwards.		

Table 6-6: Feasibility Stage, Non Traction Power Preliminary Load Assessment

6.10.2. Traction Power

The consumption of traction electrical power is closely related to the rolling stock characteristics, the service levels required and the permanent way geometry.

(Based on rolling stock configurations in Chapter 2)		
System Information	**2021**	**2041**
No of Cars	6	9
Headway, minutes	4.5	3.5
No of trains/hr/direction	13	17
Train Load at 160 km/hr maximum speed (MW)	1.90	3.00
Estimated Traction Power (MVA)	76	140
System With Regeneration (MVA)	61	112
Estimated Energy Consumption per annum (MWh)	350,000	644,000

Table 6-7: Feasibility Stage, Traction Power Preliminary Load Assessment

6.10.3. Electricity Supply Quality

The recommended Negative Phase Sequence (NPS) levels of 1.5% for short term 'one minute average' and 0.75% for longer term 'half hour average' shall be applied to the traction power design.

The incoming grid power supplier shall use these NPS levels to decide on the optimum supply voltage e.g.132kV, 230kV or 400kV.

At this stage it should be envisaged that there are no reactors and or filters required at the substation.

The Total Harmonic Distortion (THD) level for harmonics at the point of common coupling shall be within agreed limits with the supply authority or in accordance with Engineering Recommendation G5/4 "Planning Levels for Harmonic Voltage Distortion and connection of Non-linear Equipment to Transmission Systems and Distribution Networks as used in the UK".

6.10.4. Approximate Site Areas

The approximate land area required for the for the traction system electrical supplies required along the route of the railway are as follows:

- 2 no BSP Grid Feeder stations – each of approximately(*) 700m^2
- 2 no ATFS Auto Transformer Feeder Stations each approximately 2,300m^2 adjacent to the BSP's above.
- ATS Auto Transformer Stations along the route as indicated on Figure 10.2 each- approximately- 1,500m^2.

(*) Subject to supply authority confirmation

6.11 Overhead Line Equipment (OLE)

Due to the type and nature of the rolling stock envisaged, a 25kV ac overhead catenary system with train mounted pantograph collectors provides the most suitable system to power the rolling stock.

6.11.1. Depot Feeding Arrangements

Power requirements for train stabling shall take into account the auxiliary load specified per train and the number of trains to be stabled simultaneously.

6.11.2. Spare Capacity

It is recommended a spare capacity of 10% shall be provided in the traction power supply system to allow for the recovery from a perturbed train service, following a degraded mode situation or system failure, within a timescale which is acceptable to the operator.

6.11.3. Auto Transformer Sites

Auto transformers are designed to provide parallel current paths to the trains under normal feeding conditions and reduce voltage sags on the system. The (ATS) sites can be utilised to provide sectioning and disconnection under first emergency, second emergency and degraded feeding arrangements, and where appropriate for midpoint sectioning, all are recommended to be remotely controlled from the SCADA system.

The traction supply system is based on the signaling system operating on the following for train detection:-

- axle-counters
- joint less track circuits
- transmission based system

Therefore both the running rails of each track are available as paths for the fault current and traction current return to the feeder stations.

6.11.4. Earthing & Bonding

The earthing and bonding system is recommended to ensure that the short time touch voltages/potentials for the entire route under fault conditions shall be compliant with Indian Railways safety standards and always be less than the EN 50122-1 and CCITT limits, for any practical rail to-earth resistance values, e.g. 2Ω.km (wet condition), 10Ω.km (dry condition) and 100 Ω.km (very dry condition).

The temporary accessible voltages for the entire route under all normal and degraded operations (but not fault conditions) shall conform to the EN 50122-1 limits.

The permanent accessible voltages for the entire route under all normal and degraded operations (but not fault conditions) shall always be less than the EN 50122-1 limit of 60V RMS, except in workshops and similar locations where it shall be less than 25V RMS for any practical rail-to-earth resistance values, e.g. 2Ω.km (wet condition), 10Ω.km (dry condition) and 100 Ω.km (very dry condition).

It may be necessary to cross-bond the two tracks of the system, to be compliant with the permissible touch and accessible voltages specified in EN50122-1.

The following assumptions have been made during the preparation of this document:-

- accessible voltage in stations, depot and workshop shall be limited to 25 V RMS under normal operating conditions.
- the accessible voltage in locations other than above shall be limited to 60V RMS maximum.
- the touch voltage in stations, depot and workshop shall be limited to 430 V RMS under fault conditions.

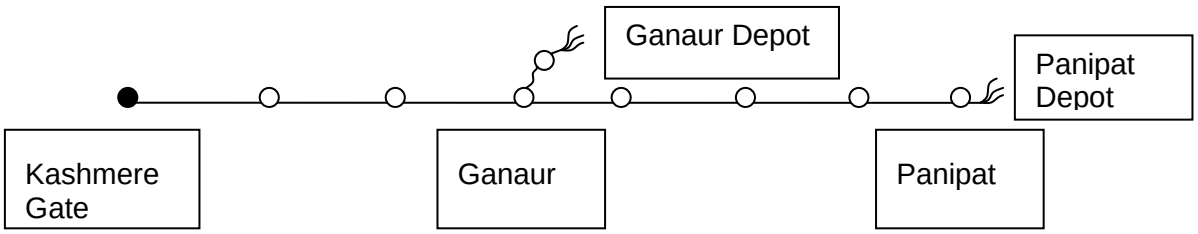
The typical OLE system architecture is indicated in Figure 10.3 below:

6.12 Train Maintenance Depot and Stabling

The train maintenance depots will provide all the necessary facilities for maintenance, operations and stabling for the railway. The depots will also provide the human requirements such as changing areas for maintenance staff and office space for the rail administration staff. It is proposed that there will be two depots one located at Ganaur and one at Panipat. Panipat will be the primary depot location and the Ganaur site will provide limited stabling for early morning services and light maintenance facilities. Ganaur will also provide some back up facilities such as a slave operations control room.

6.12.1. General Background and Design Process

The new railway requires stabling, maintenance, administration and the Operations Control centre near Panipat at the north end of the proposed alignment. Further stabling will be provided near Ganaur to service early morning and Ganaur – Kashmere Gate services. Ganaur depot will also provide backup resources in case of any requirement to shut down the Panipat site.



The key requirements for the depot were identified following an assessment of passenger flows against capacity of rolling stock. This was based on existing rolling stock configurations which are available in the market. Recent depot projects were also reviewed. The depot was then sized based on the provisional fleet size and the facilities required in the depot in order to develop a design schedule and layout to meet the predicted requirements

6.12.2. Depot Capability Summary

Based on the need to provide a more intense service between Kashmere Gate and Ganaur, a small depot is proposed at Ganaur to reduce ongoing revenue costs associated with empty coaching moves to Panipat depot and support the early services from Kashmere Gate. Panipat depot is proposed as the main depot and the facilities provided at each depot will be based on the following:

Ganaur

- all daily inspections and daily cleaning
- all minor repairs (light bulbs, window wipers etc)
- stabling for early morning services.

Panipat

- all daily inspections of all other rolling stock
- all "A" service checks (5,000km intervals)
- all "B" service checks (15,000km intervals)
- all minor repairs of all other rolling stock
- all intermediate overhauls (IOH) of all rolling stock (400,000km intervals)
- all periodic overhauls (POH) of all rolling stock (800,000km intervals)
- all stabling of all other rolling stock
- all heavy repairs (bogie change etc)

6.12.3. Stabling Requirements

Based on the provisional fleet size of 34 trains provided in Chapter 2 (All-Stations) and the provisional timetable provided in Chapter 7 the depot requirements for 2021 were assessed as follows.

	Panipat Depot		Ganaur Depot	
	2016	2041	2016	2041
Service Fleet	23	29*	6	8
Hot Standby	1	2	1	1
Maintenance	3	4	0	0
Total	27	35	7	9

Table 6-8: Fleet Size Breakdown (2021)

In order to support the early/late services in to and out of Kashmere Gate and reduce the extent of empty stock moves between Panipat and Delhi it is estimated that 6 trains will require stabling at Ganaur Depot with an additional hot spare provided to support service recovery.

The required 2021 capacity at Panipat Depot will therefore be a total of 27 trains.

From Chapter 2 the maximum train length provided at the depot has been assumed as 238m to allow for possible future expansion from 6-car to 9-car in order to achieve the 2041 Ultimate System Capacity. This gives a maximum length of siding of 308m assuming a 15m stopping tolerance at each end and a straight length of 20m at each end to allow each car to align before entering the tight confines of the siding. Based on the above, preliminary depot layouts have been prepared for both Panipat and Ganaur and are shown in Figures 11.1 and 11.2 respectively.

7. ASSUMPTIONS AND BOUNDARY CONDITIONS

7.1 Project timelines

7.1.1. Assumptions

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

Table 7-1 : Assumptions - Timelines

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

7.2 Phasing of Initial Capital Investment

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

Table 7-2 : Implementation Phasing Plan

Sr. No.	Particulars	Year 1 (Oct 12-Oct 13)	Year 2 (Oct 13-Oct 14)	Year 3 (Oct 14-Oct 15)	Year 4 (Oct 16-Oct 17)	Total
1	Land	100%				100%
2	Civil works, Alignment and	30%	30%	40%		100%

	formation					
3	Overhead Station Buildings	20%	40%	40%		100%
4	Underground Station Buildings	20%	40%	40%		100%
5	Depot cum Workshop	100%				100%
6	Power Supply and Substations			85%	15%	100%
7	Control Systems			80%	20%	100%
8	R&R	100%				100%
9	Miscellaneous	25%	25%	25%	25%	100%
10	Rolling Stock	33%	33%	34%		100%

7.3 Taxes and Duties

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

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

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

7.4 Financial & Taxation assumptions

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

Table 7-4 : Key Financial Assumptions

Sr. No.	Particulars	Value
1	Inflation rate	5%
2	Discount rate	10%
3	Tax rate	32.45%
4	MAT	20.01%
5	80IA benefit taken from date	From COD
6	Tax holding in a block of 15 years	10 years

7	Interest rate on term loan	2%
8	Term period	20 years
9	Moratorium	Nil
10	Interest rate on future capital expenditure	10%
11	Debt equity structure for future capital expenditure	80:20
12	Repayment period for future capital expenditure	10 years

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

7.5 Depreciation Rates

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

Table 7-5 : Applicable Depreciation Rates

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

7.6 Working Capital Assumptions

Assumption related working capital estimation is as set out below.

Table 7-6 : Working Capital Assumptions

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

8. REVENUE ESTIMATION

8.1 Key Revenue Avenues

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

- Fare Box revenue
- Other sources – Revenue from rentals from commercial, transit oriented development, Advertisement,etc.

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

8.2 Fare Box Revenue

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

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

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

8.2.1. Fare Structure

The fare structure has been proposed considering the following factors:

- *Comparison with fares of various modes of public transport that are currently available between Delhi Panipat section* – The table below presents the 2010 fares of various modes of public transport that are currently operating in Delhi Panipat region along with approximate time taken to travel by these modes

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

Sr. No.	Mode	Delhi – Panipat fare (in Rs.)	Journey Time	Remarks
1	EMU – Passenger	Rs 15	2-2.5hrs	
2	Kalka Shatabdi (AC Chair Car)	Rs 285 (actual) Rs151 (Prorated)	70-80 mins	Rs 151 fare is prorated based on distance on Delhi Chandigarh full fare
3	Jan Shatabdi (AC Chair Car)	210	85 mins	
3	State Transport	65 (approx)	1.5 – 2 hrs	

	bus (Non AC)			
4	State Transport AC Volvo Bus	200 (approx)	1.5 hrs	

- *Passengers' willingness to shift from their current mode of transport to RRTS* – As indicated in the travel demand forecast section of this report, the passenger willingness to shift has been conducted at three different price points of Rs 50, Rs. 100 and Rs. 150. As suggested by the Travel demand forecast survey the commuters travelling by personal vehicle (primarily cars and taxis) have shown highest willingness to shift making them one of the prime target customers of RRTS. Also daily commuters travelling by state transport (Non AC) buses would also be willing to shift considering the saving in journey time achieved by shifting from bus to RRTS.

The table below provides the distance matrix used for deriving the fare between stations.

Table 8-2 : Distance between Stations

KM	Kashmere	Mukharba	Narela	Kundli	KMP EH	RGEU	Murthal	Ganuar	samalkha	Panipat	IOCL
Kashmere Gate	0	14	23	28	36	38	48	63	72	90	99
Mukharba Chowk	14	0	9	15	23	24	34	49	58	76	85
Narela	23	9	0	6	14	16	25	40	50	67	76
Kundli	28	15	6	0	8	10	20	34	44	62	71
KMP EH	36	23	14	8	0	2	12	26	36	54	63
RGEU	38	24	16	10	2	0	10	24	34	52	61
Murthal	48	34	25	20	12	10	0	15	24	42	51
Ganuar	63	49	40	34	26	24	15	0	10	27	37
samalkha	72	58	50	44	36	34	24	10	0	18	27
Panipat	90	76	67	62	54	52	42	27	18	0	9
IOCL	99	85	76	71	63	61	51	37	27	9	0

Fare Structure for full one way fare Delhi – Panipat City

Considering the above factors a fare of Rs 100 (at 2011 levels) is proposed between Kashmere Gate station and Panipat City station. The fare for Delhi to IOCL Panipat has been calculated on prorate basis, based on distance. This fare is calculated as Rs 110. The fare for subsequent years has been proposed to be increased at a nominal rate 5% per annum for the entire period of the project.

Fare structure for intermediate stops

It has been observed that in other similar projects like Delhi Metro or AC fare of Shatabadi trains of Indian Railways, Telescopic fare structure has been adopted. A similar structure is proposed for Delhi Panipat RRTS. It has been assumed that the minimum fare for a single journey would be kept at 25% of full fare between Kashmere Gate and Panipat City station. Beyond this the fare would be prorated based on distance between the boarding and alighting stations.

The table below provides the fares between the stations based on telescopic fare structure (2011 fare), minimum fare 25% of Delhi Panipat City Fare (Rs 100)

Table 8-3 : Station wise Proposed Telescopic full fare

Rs/ticket	Kashmere G	Mukharba Ch	Narela	Kundli	KMP EH	RGEU	Murthal	Ganuar	samalkha	Panipat	IOCL
Kashmere Gat	0	25	25	32	40	42	53	70	80	100	110
Mukharba Ch	25	0	25	25	25	27	38	54	65	85	95
Narela	25	25	0	25	25	25	28	44	55	75	85
Kundli	32	25	25	0	25	25	25	38	49	68	79
KMP EH	40	25	25	25	0	25	25	29	40	60	70
RGEU	42	27	25	25	25	0	25	27	38	58	68
Murthal	53	38	28	25	25	25	0	25	27	47	57
Ganuar	70	54	44	38	29	27	25	0	25	30	41
samalkha	80	65	55	49	40	38	27	25	0	25	30
Panipat	100	85	75	68	60	58	47	30	25	0	25
IOCL	110	95	85	79	70	68	57	41	30	25	0

Fare structure for monthly pass passengers

It has been observed that there are many passengers commuting between Delhi Sonepat and Delhi Panipat on a daily basis. For the benefit of such commuters and for assisting their shift to the RRTS from their current modes of travel, a monthly pass fare is also suggested. A rebate of 25% on the journey fare is considered for the commuters opting for the monthly pass. Thus the Delhi – Panipat city one way fare considered for monthly pass passengers is Rs 75.

The table below provides the monthly pass fares between the stations based on telescopic fare structure (2011 fare), minimum fare 25% of Delhi Panipat City Fare (Rs 75)

Table 8-4 : Station wise Proposed Telescopic Fare for monthly pass

Rs/ticket	Kashmere Gate	Mukharba Chowk	Narela	Kundli	KMP EH	RGEU	Murthal	Ganuar	samalkha	Panipat	IOCL
Kashmere Gate	0	19	19	24	30	32	40	52	60	75	83
Mukharba Chowk	19	0	19	19	19	20	29	41	49	63	71
Narela	19	19	0	19	19	19	21	33	41	56	64
Kundli	24	19	19	0	19	19	19	28	36	51	59
KMP EH	30	19	19	19	0	19	19	22	30	45	52
RGEU	32	20	19	19	19	0	19	20	28	43	51
Murthal	40	29	21	19	19	19	0	19	20	35	43
Ganuar	52	41	33	28	22	20	19	0	19	23	30
samalkha	60	49	41	36	30	28	20	19	0	19	22
Panipat	75	63	56	51	45	43	35	23	19	0	19
IOCL	83	71	64	59	52	51	43	30	22	19	0

8.2.2. Ridership Estimation

The ridership of RRTS Delhi Panipat corridor has been estimated in detail under various scenarios of speed, waiting time and fare structure.

As per the detailed engineering feasibility study, the RRTS is proposed to have an operating average speed of 160km/h. By running a simulation on MTrail simulation Software it has been found out that for Delhi Panipat stretch with 160kmph average speed and train stopping at all intermediate stations, the one way journey from Kashmere Gate station to Panipat City station shall be completed in approximately 74 mins. Also the frequency of trains as per the detailed train schedule as given in Engineering and Operations report ranges from 4.5mins in 2016 to 2.5 mins in 2041 between Kashmere Gate and Gannuar. This would translate to an average waiting time of nearly 2.5 mins for the passengers.

Considering the above, the table below provides the daily ridership of RRTS between Delhi and Panipat for variables namely, (a) Full Fare (Kashmere Gate – Panipat City) = Rs. 100; (b) Concessional fare/ monthly pass fare (Kashmere Gate – Panipat City) = Rs 75 (c) Travelling time from KG to Panipat city = 74mins and (c) waiting time of 2.5 mins

Table 8-5 : Estimated daily Ridership

Year	Total ridership (in lakhs per day)
2016	3.77
2021	5.47
2031	7.79
2041	9.83

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

8.2.3. Revenue Estimation

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

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

Based on the fare and ridership estimate as discussed in the articles above, the table below summarizes the yearly revenue estimate from FY 2016-2017 till 20045-46.

Table 8-6 : Estimated Yearly Fare Box Revenue

Sr. No.	Financial Year	Yearly Fare Box Revenue (Rs. Millions)
		Total Revenue
1	FY-2017*	3070
2	FY- 2018	7575
3	2019	9546
4	2020	10828

5	2021	12281
6	2022	13929
7	2023	15104
8	2024	16378
9	2025	17760
10	2026	19258
11	2027	20882
12	2028	22644
13	2029	24554
14	2030	26626
15	2031	28872
16	2032	31307
17	2033	33619
18	2034	36102
19	2035	38768
20	2036	41630
21	2037	44704
22	2038	48006
23	2039	51550
24	2040	55357
25	2041	59445
26	2042	63835
27	2043	68548
28	2044	73610
29	2045	79046
30	2046	84883

*considering 6 months operations in FY17

8.3 Other Revenue Sources

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

a) Commercial Areas in station building complex
b) Advertisement Panels
c) TOD zones

8.3.1. Commercial Area in station building complex

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

- location of station– commercial potential
- type of stations – elevated and underground
- area at concourse level
- land availability
- Current rental values in the city and rent escalation potential
- State/ district development plans

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

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

Table 8-7 : Station wise Property Development Proposed

Sr. No.	Stations	Commercial area in station building (Sqm)	Retail area in secondary building (sqm)	Rental value (Rs/ sqm) 2011	Starting occupancy (%)
1	Panipat IOCL	52486	0	200	40%
2	Panipat City	85285	0	300	50%
3	Samalkha	26696	0	150	40%
4	Gannaur city	27483	0	150	40%
5	Gannaur depot	52486	0	150	40%
6	Murthal	7932	17058	200	50%
7	RGEU	46591	13570	200	40%
8	KMP interchange	36205	13570	200	40%
9	Kundli	20251	6216	200	50%
10	Narela	84042	0	200	40%
11	Mukarba Chowk	3658	17025	300	50%
12	Kashmere Gate	382		300	60%

8.3.2. Advertisement Panels

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

- Advertisement panels inside the 12 proposed station locations
- Advertisement panels inside and outside the train
- Advertisement on viaduct at potential places wherever possible.
- Digital displays inside the stations and trains.

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

The table below provides the details of revenue from rentals on commercial areas inside the station buildings and secondary buildings and the revenue from advertisement.

8.3.3. Revenue Estimates from Commercial and Advertisement

Table 8-8 : Commercial and Advertisement Revenue

Sr. No.	Financial Year	Commercial and Advertisement Revenue (Rs. Millions)		
		Revenue from station commercial and other commercial areas around stations	Advertisement Revenue	Total
1	FY-2017*	723	31	754
2	FY- 2018	987	76	1063
3	2019	1348	95	1443
4	2020	1765	108	1874
5	2021	2001	123	2124
6	2022	2101	139	2240
7	2023	2206	151	2357
8	2024	2316	164	2480
9	2025	2432	178	2610
10	2026	2554	193	2746
11	2027	2682	209	2890
12	2028	2816	226	3042
13	2029	2956	246	3202
14	2030	3104	266	3370

15	2031	3259	289	3548
16	2032	3422	313	3735
17	2033	3594	336	3930
18	2034	3773	361	4134
19	2035	3962	388	4350
20	2036	4160	416	4576
21	2037	4368	447	4815
22	2038	4586	480	5066
23	2039	4816	516	5331
24	2040	5056	554	5610
25	2041	5309	594	5904
26	2042	5575	638	6213
27	2043	5853	685	6539
28	2044	6146	736	6882
29	2045	6453	790	7244
30	2046	6776	849	7625

8.4 Transit Oriented Development Zones

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

8.4.1. Potential TOD area statement

The table below summarizes the TOD area and provides the details of the TOD zones and area considered for further analysis in the business plan report.

Table 8-9 : Potential TOD area statement

Sr. No.	TOD Zones	Potential Area marked on Map (Ha)- *(subject to change after discussions with state Govt.)*	Area taken for analysis in Business Plan (Ha)	Proposed Land use
1	IOCL Panipat Depot	1090	600	Mixed

Sr. No.	TOD Zones	Potential Area marked on Map (Ha)- *(subject to change after discussions with state Govt.)*	Area taken for analysis in Business Plan (Ha)	Proposed Land use
2	Samalkha	525	300	Mixed
3	Gannaur Depot	1085	600	Mixed
	Total		**1500**	

We have taken a conservative view on the potential TOD area and have only taken 1500 hectares for revenue calculations in the business plan out of 2700 hectares identified. This gives enough room for against adjustment or any downside in revenues arising out of TOD.

According to Urban Development Plans Formulation and Implementation (UDPFI) guidelines used for city development strategies, the density in a city can range between 150 to 350 persons per hectare (pph). Hence it is assumed that the TOD zone will be a medium population density area with a density of 225 pph. Out of the total 1500 hectares land area, 60% of the area proposed for development in terms of the table given below.

Table 8-10 : Proposed Built-up area in TOD zones

Sr. No.	Description	%	Developed Area	FAR	Built-up Area
1	Total Area	1500 ha			
2	Developed Area	60%			
a	Residential	30%	450 Ha	3	1350 Ha
b	Commercial	10%	150 Ha	3	450 Ha
c	Office	20%	300 Ha	4	1200 ha
d	Green Area / Roads/Common area /others	40%	600 Ha	-	-

8.5 Transaction Cess on TOD

Development strategy

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

Table 8-11 : Proposed Cess Rate

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

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

Total Cess for the year = Rs. 1,000 per sqm per transaction X Total TOD area X velocity of transaction for the corresponding year.
The cess could be applied within 3 months of the release of this Report to capture the initial burst of Capital inflow into the TOD zone. This amount during construction of the project could be utilized towards state government's equity contribution for the project. Further it is assumed that the state government would come out with development plan for TOD area within next six months itself.
Following table provides year wise estimated Cess during the construction period.

Table 8-12 : Estimated Transaction Cess during Construction

Sr. No.	Year	Velocity of Transaction	Built up Area	Total Cess
		%		Rs. Million
1	2012	5%	3000 ha	750
2	2013	10%	3000 ha	1500
3	2014	20%	3000 ha	3000
4	2015	20%	3000 ha	3000
	Total			**8250**

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

and after a period of time this could reduce gradually towards the end of the project period (5%).

The table below gives the detailed year wise estimated revenue from cess and the total amount of fund generated upto 2046. The Transaction Cess fund would be used to repay the soft loan including interest and principal.

Table 8-13 : Estimated Transaction Cess after Construction

Sr. No.	Year	Velocity of Transaction	Residential	Commercial	Office	Total Cess
		%	Rs. Million			
			@Rs.1000	@Rs.2000	@Rs.1500	
1	2016	20%	2700	1800	3600	8100
2	2017	15%	2025	1350	2700	6075
3	2018	15%	2025	1350	2700	6075
4	2019	15%	2025	1350	2700	6075
5	2020	14%	1890	1260	2520	5670
6	2021	14%	1890	1260	2520	5670
7	2022	14%	1890	1260	2520	5670
8	2023	13%	1755	1170	2340	5265
9	2024	13%	1755	1170	2340	5265
10	2025	13%	1755	1170	2340	5265
11	2026	12%	1620	1080	2160	4860
12	2027	12%	1620	1080	2160	4860
13	2028	12%	1620	1080	2160	4860
14	2029	11%	1485	990	1980	4455
15	2030	11%	1485	990	1980	4455
16	2031	11%	1485	990	1980	4455
17	2032	10%	1411	941	1881	4232
18	2033	10%	1340	893	1787	4021
19	2034	9%	1273	849	1698	3820
20	2035	9%	1210	806	1613	3629
21	2036	9%	1149	766	1532	3447
22	2037	8%	1092	728	1455	3275
23	2038	8%	1037	691	1383	3111
24	2039	7%	985	657	1314	2956
25	2040	7%	936	624	1248	2808

Sr. No.	Year	Velocity of Transaction	Residential	Commercial	Office	Total Cess
		%	Rs. Million			
26	2041	5%	889	593	1185	2667
27	2042	6%	845	563	1126	2534
28	2043	6%	802	535	1070	2407
29	2044	6%	762	508	1016	2287
30	2045	5%	724	483	966	2173
31	2046	5%	688	459	917	2064
	Total		**2700**	**1800**	**3600**	**8100**

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

Table 8-14 : Summary of Project Revenue

Sr. No.	Revenue Stream	FY2018	FY2022	FY2032	FY2042
		Rs. Million /Year			
1	Fare box	7575	13929	31307	63835
2	Revenues from station commercial	987	2101	3422	5575
3	Revenue from advertisement	76	139	313	638
4	Transaction Cess on TOD post construction	6075	5670	4232	2534
5	**Total Project Revenue**	**14713**	**21839**	**39275**	**72582**

9. CAPITAL COST ESTIMATION

9.1 Introduction

Capital Cost estimate for the proposed RRTS Delhi Sonepat Panipat corridor has been prepared covering the cost heads for the following areas at 2011 price levels:

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

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

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

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

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

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

9.2 Capital Cost Estimation Basis

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

- For each system and works like Viaduct, Tunnels, Rolling Stock, Power Supply, Signals, Communications, AFC, Depots, M&P etc a list of items and quantities has been prepared based on the consultant's experience, traffic studies, operations simulation and alignment survey.
- The rates of different items have been assessed from market prices or rates from similar works in Indian Railways and Metro projects in India.
- For elevated viaduct, the actual BOQ has been worked out and current Delhi Metro rates have been used to work out the cost.
- For station costs, a separate study for conceptual design and costs has been conducted.
- A suitable escalation factor has been applied to bring these estimated costs from other metro and rail projects to current price level.
- Cost of M&P has been taken from Indian Railways COFMOW purchase rates and where these are not available, from rates in other Indian Railways or Metro projects.
- Taxes & Duties such as Customs Duty, sales Tax, Works Tax, VAT, etc., wherever applicable, have been worked out on the basis of prevailing rates and included in the cost estimates separately.
- An escalation factor of 5% per year from previous costs has been assumed in arriving at costs of 2011

9.3 Civil Engineering Works

9.3.1. Land

The land required for the project has been kept at the barest minimum level and worked out on area required basis. It has been tried to keep the private land acquisition at a minimum level. In Haryana portion of the alignment, after Samalkha station, it has been tried to utilize the 50m green belt alongside of NH1 to keep the land acquisition at a minimum level. The government land has not been valued and the cost of acquiring private land is based on the circle rates presently being charged by the authorities in Haryana and Delhi. The land required for the project in Delhi falls completely under government authorities.

Compensation for private land acquisition: Private land would be acquired where necessary in the state of Haryana and the compensation to be paid for private land for acquisition has been estimated at the circle rate of Rs 8.64 lacs / hectare in Sonepat region and 6.67 lakhs/ hectare in the Panipat region.

Annual Rehabilitation grant: Apart from the on time payment for land acquisition, we propose an annual payment equivalent to 1% of land cost (at 2011 prices) to be escalated at 5% per annum to the individual land owners for the entire concession period of the project (till FY2046).

The table below provides the details of the total land required for the project along with the cost of acquisition in various zones along the alignment

Table 9-1 : Estimated land requirement

Sr. No.	Location of Land	Use Description	Area (in hectares)		Circle Rate (Rs crs/hectare)	Total Cost for Pvt. Land (Rs Crs)
			Ownership			
			Govt.	Pvt.		
1	**Delhi**					
1.1	Along Corridor	Alignment	77.2	0.0	9.14	-
1.2	Mukarba Chowk	Station	3.4	0.0	9.14	-
1.21	Narela	Station	9.9	0.0	9.14	-
1.22	KG Terminus	Station	2.0	0.0	9.14	-
	Total for Delhi		**92.5**	**0.0**		**0**
2	**Haryana -Sonepat**					
2.1	Along Corridor	Main Alignment	112.8	0.0	8.64	-
2.2	Along Corridor	Spur Alignment	0.0	14.7	8.64	127
2.3	Kundli	Station	4.2	0.0	8.64	-
2.31	KMP Interchange	Station	6.5	0.0	8.64	-
2.32	Rajiv Gandhi Edu City	Station	7.5	0.0	8.64	-
2.33	Murthal	Station	4.8	0.0	8.64	-
2.34	Ganaur City	Station	4.3	0.0	8.64	-
2.4	Ganaur Area	Depot	0.0	105.0	8.64	907
	Total for Sonepat		**140.0**	**119.7**		**1,034**
2	**Haryana - Panipat**					
2.1	Along Corridor	Main Alignment	0.3	87.6	6.67	584
2.2	Samalkha	Station	0.0	4.2	6.67	28
2.21	Panipat City	Station	0.0	10.1	6.67	67
2.3	IOCL Panipat	Depot	0.0	210.0	6.67	1,401

Sr. No.	Location of Land	Use Description	Area (in hectares)		Circle Rate (Rs crs/hectare)	Total Cost for Pvt. Land (Rs Crs)
	Total for Sonepat		**0.3**	**311.8**		**2,080**
	GRAND TOTAL		**233**	**432**		**3,114**

9.3.2. Alignment

9.3.2.1 Underground Section

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

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

9.3.2.2 Elevated Section

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

9.3.3. Stations

9.3.3.1 Underground Stations

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

The cost for OHE, Permanent Way, Signaling and Telecommunication, Automatic Fare Collection at stations have been taken separately in the costs of these items and have not been included in the station costs. The station conceptual designs as well as the costs have been prepared by professional architects appointed for this purpose.

9.3.3.2 Elevated Stations

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

The cost for OHE, Permanent Way, Signaling and Telecommunication, Automatic Fare Collection at stations have been taken separately in the costs of these items and have not been included in the station costs. The station conceptual designs as well as the costs have been prepared by professional architects appointed for this purpose.

9.4 Depots

The RRTS corridor will have a depot cum workshop at IOCL Panipat and a sub depot at Gannaur. For each depot a layout and size of trackwork, repair sheds, stabling lines, maintenance buildings, Stores building, Administrative office, Canteen, Water supply, etc has been estimated in detail. The cost of these items are based on the schedule of rates, the rates adopted by Indian Railway Workshops and new Metro Rails in India.

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

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

9.5 Rolling Stocks

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

9.6 Traction and Power Supply

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

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

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

9.7 Permanent Way

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

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

9.8 Automatic Fare Collection

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

9.9 Signalling and Telecommunication Works

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

9.10 General Charges and Contingencies

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

9.11 Capital Cost estimate

9.11.1. Base Capital Cost

The following table estimates the basic cost at 2011 levels for various heads as stated above along with the basis of estimation as well as inclusions/ exclusions.

Table 9-2 : Estimated Capital Cost for base year 2011

Item	Description	Units	Quantity	Rate (Rs. Crore/ per Unit)	Sub-Total (Rs. Crore)	Total (Rs. Crore)
1.0	**Land**					**3114**
1.1	Private Land	Hectare	432.0	-	3114.0	

1.2	Government land	Hectare	233.0	-		
2.0	**Civil works, Alignment and formation**					**3319**
2.1	Tunneling Work	R Km	2.240	152.9	342.4	
2.2	Ramp - underground	R Km	0.325	47.3	15.4	
2.3	Ramp - Elevated	R Km	0.975	18.5	18.1	
2.4	Elevated Viaduct	R Km	93.990	30.0	2819.7	
2.5	At grade Alignment	R Km	7.180	1.5	10.9	
2.6	Single Track Viaduct	R Km	2.800	-	-	
2.61	Single Track Viaduct	Total Km	5.000	22.5	112.5	
3.0	**Station Building**		12.0			**1472**
3.1	Underground Terminal Station	Nos.	1.0	265.0	265.0	
3.2	Elevated Stations	Nos.	9.0	113.0	1017.0	
3.3	At grade Terminal Station	Nos.	2.0	95.0	190.0	
4.0	**E&M Works**		12.0			**339**
4.1	Electro mechanical works including Lifts, Escalators, DG sets, UPS,ECS					
4.11	Underground station	Nos.	1.0	67.3	67.3	
4.12	Elevated station	Nos.	9.0	26.7	240.1	
4.13	At grade station	Nos.	2.0	13.3	26.7	
4.2	Tunnel Ventillation	R Km	1.5	3.2	4.7	
5.0	**Depot-cum-Workshop**		2.0			**206**
5.1	IOCL Panipat Depot					
5.11	Civil works, Track work, OHE	Nos.	1.0	84.6	84.6	
5.12	Plant and Machinery	Nos.	1.0	77.0	77.0	
5.2	Gannaur Depot					
5.21	Civil works, Track work, OHE	Nos.	1.0	24.1	24.1	
5.22	Plant and Machinery	Nos.	1.0	20.0	20.0	
6.0	**Permanent Way**					**722**
6.1	Ballastless track for elevated & underground alignment	R KM	104.1	6.5	674.2	
6.2	Ballasted/Embedded track for at grade allignment	R KM	17.2	2.8	48.1	
7.0	**Traction & Power Supply incl. OHE, ASS etc.**					
7.1	Under Ground Section	R KM	2.57	8.7	22.3	
7.2	Elevated & At Grade Section	R KM	120.9	6.8	821.9	

8.0	**Signalling and Telecom.**					**840**
8.1	Signalling	R KM	121.2	6.3	768.3	
8.2	Telecom.	No. of Stations	12.0	6	72.0	
9.0	**Automatic fare collection**					**56**
9.1	Ticketed Stations	No. of Stations	12.0	4.7	56.4	
10.0	**R & R**					**56**
10.1	R & R incl. Hutments and road restoration etc	R KM	111.2	0.5	55.6	
11.0	**Misc. Works**					**177**
11.1	Utilities Relocation	R KM	111.2	0.5	55.6	
11.2	Misc. civil works such as median, road signages	R KM	111.2	0.5	55.6	
11.3	Barracks for Security Staff including security equipments	Nos.	12.0	0.5	6.0	
11.4	Staff Quarters for O&M	Nos.	12.0	5.0	60.0	
12.0	**Rolling Stock**					**2142**
12.1	EMU Coaches	Nos.	204.0	10.5	2142.0	
13.0	**Miscellaneous Items**					**138**
13.1	Training	Nos.	1.0	10.0	10.0	
13.2	Spares (%of 7,8,9 & 12)	%	2%	3882.9	77.7	
13.3	Testing and Commissioning Costs	Nos.	1.0	50.0	50.0	
14.0	**Total**					
14.1	Total (Including Land Cost)	Sum (1 to 13)			**13425.2**	
14.2	Total (Excluding Land Cost)	Item 14.1 Less 1			10311.2	
14.3	General Charges incl. Design charge	% of 14.2	10311.2	5%	515.6	
14.4	Contingency	% of 14.1+14.3	13940.7	5%	697.0	
	Estimated Construction Cost on Year 2011 Basis (Excluding Land)					**11524**
	Estimated Construction Cost on Year 2011 Basis					**14,638**

9.11.2. Base Capital Cost with taxes and duties

The table below provides the details of Capital cost including central taxes (customs duty and excise duty) and state taxes (VAT).

Table 9-3 : Base capital cost with taxes and duties

Sr. No.	Components	Amount in Rs. Million
1	Land	3114
2	Base Construction Cost (excl. land cost & General Charges and Contingency)	103112
3	**Total Base Project Cost**	**134252**
4	Total Central Taxes	**11007**
a	Customs Duty	7159
b	Excise Duty	3848
5	Cost including Central Taxes (3+4a+4b)	145259
6	State Tax (VAT)	**6358**
7	Cost including State Tax (5+6)	151617
8	General Charges @5% on (7 -1)	6024
9	Contingency @5% on (7+8)	7882
10	**Total Cost (incl. taxes excl. IDC)**	**165522**

9.11.3. Capital expenditure for future expansion and replacements

The following table gives the capex requirement for future expansion and replacement of equipment such as rolling stock, E&M, track work etc.

Table 9-4 : Expansion and Replacement CAPEX Investment Phasing Plan

Particulars/ Year Capex in Rs Crs on 2011 prices	2021 (FY 22)	2031 (FY-32)	2036 (FY37)
Rolling stock	842.1	1435	
E&M cost			1424.9
Track work		78.9	

These costs are exclusive of taxes and duties.

9.11.4. CAPEX Phasing

The table below specifies the year wise requirement of funds for capital expenditure.

Table 9-5 : Year wise actual capital expenditure required (including IDC and margin money)

Component (Cost in Rs Mil)	FY13	FY14	FY15	FY16	FY17	Total
Land	10380	20760	0	0	0	62280
Civil works, Alignment and formation	5348	15368	20936	11210	0	105727
Overhead Station buildings	1792	5646	7904	4150	0	38983
Underground Station buildings	413	1301	1822	956	0	8985
Depot-cum-Workshop	0	864	1396	513	0	5548
Power supply and substations	0	0	4923	6082	958	23925
S&T (excluding onboard) and AFC	0	0	4950	6497	1364	25625
Resettlement and rehabilitation	207	434	0	0	0	1282
Miscellaneous	476	999	1049	1102	579	8411
Rolling Stock	4382	9203	9809	5227	0	57242
Total	22999	54576	52791	35737	2901	169004
Other charges(contingency and project management)	1987	4951	5028	3574	305	15845
total capital cost without IDC	24986	59527	57819	39311	3205	184849
IDC	0	0	333	1246	733	2313
Total Capital cost without Margin money	24986	59527	58152	40558	3938	187161
Margin money	0	0	0	0	390	390
Total capital cost	24986	59527	58152	40558	4328	187551

10. OPERATIONS & MAINTENANCE COST ESTIMATION

10.1 Introduction

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

- Staff costs
- Energy cost
- Maintenance cost

10.2 Staff cost

10.2.1. Staff Cost

The total number of staff in different categories namely train operation, maintenance staff at depots and station staff at each location has been assessed for the RRTS. This assessment is based on contemporary staffing pattern on Metro Rail systems, suitably modified to account for the lesser number of stations on the RRTS The number of train drivers has been calculated based on the duty hours and the number of trains to be run. The staff requirement is estimated at 2,312 personnel for the initial phase (2017) and subsequently for every 5 year from COD an incremental increase in manpower is considered at 10%. Accordingly, the number of staff per km is estimated about 23 persons (for the year 2018) and the total estimated manpower cost is at Rs. 795 Million per year based on the constant price (i.e. 2011 base year price).

Further an adjustment has been made year on year basis at the rate of 8% from the base year. For the first full year (i.e. 2018) of operation the annual estimated cost is about Rs. 1,363 Million. Year wise estimated annual manpower cost is as given below.

Table 10-1 : Staff cost

Number of Staff	
Main Depot	615
Second Depot	63
Train Crew	326
Station Staff	1,308
Total Staff Number	**2,312**
Salary Cost, Rs Mil per year	**Rs Mil/year**

FY 2018	1363
FY2021	1888
FY2031	4933
FY2041	12885

10.3 Energy cost

10.3.1. Base energy Cost

Base energy costs (at 2011 cost levels) have been calculated for 3 blocks of years namely 2016-2021, 2021-2034 and 2035-2041. The estimation of the energy cost has been done based on the energy consumption in the following areas

- Energy consumption in traction
- Energy consumption in station
- Energy consumption in depot

10.3.1.1 Energy consumption in traction

The energy consumption in traction is based on the train operations schedule and total energy consumed by the train in one trip from Kashmere gate to IOCL Panipat station and Kashmere Gate station to Gannaur Depot station. The table below summarizes the assumptions and energy consumption calculations for traction:

Table 10-2 : Energy consumed in traction power

Timeline	Route	No of Cars per train	Single trip journey time, mins	Terminus dwell time, mins	Round trip time, mins	Single trip energy consumed, kWh	Energy consumed per round trip, kWh	Energy consumed per train per hour, kWh	No. Of trains on the route	Energy consumed by all the trains per hour, kWh	Energy consumed by all the trains per hour, with 15% losses, kWh	Energy consumed by all the trains per hour, with 10% contingency, kWh	Energy consumed by all the trains per hour, with regeneration, kWh	Traction Energy per route per year, kWh
2016 to 2020	KG to IOCL	6	73	4.5	155	2,235	4,470	1,730	18	31,146	36,642	40,713	32,571	221,025,299
	KG to Ganaur	6	41	4.5	91	1,255	2,511	1,655	11	18,208	21,422	23,802	19,041	129,215,160
	Total Traction Energy per year, kWH													**350,240,460**
	Total Traction Demand kVA 2016 to 2021 with 0.85 power factor													**60,720**
2021 to 2034	KG to IOCL	9	73	4.5	155	3,350	6,700	2,594	18	46,684	54,922	61,025	48,820	331,290,717
	KG to Ganaur	9	41	4.5	91	1,882	3,763	2,481	11	27,292	32,108	35,676	28,541	193,678,204
	Total Traction Energy per year, kWh													**524,968,921**
	Total Traction Demand kVA 2021 to 2034 with 0.85 power factor													**91,012**
2035 to 2044	KG to IOCL	9	73	3.5	153	3,350	6,700	2,627	22	57,804	68,005	75,561	60,449	410,203,829
	KG to Ganaur	9	41	3.5	89	1,882	3,763	2,537	13	32,979	38,799	43,110	34,488	234,036,073
	Total Traction Energy per year, kWh													**644,239,902**
	Total Traction Demand kVA 2034 to 2044 with 0.85 power factor													**111,690**

2044+	KG to IOCL	12	73	3.5	153	4,465	8,930	3,502	22	77,043	90,639	100,710	80,568	546,734,358
	KG to Ganaur	12	41	3.5	89	2,508	5,015	3,381	13	43,956	51,713	57,459	45,967	311,931,662
	Total Traction Energy per year, kWh													**858,666,019**
	Total Traction Demand kVA 2044+ with 0.85 power factor													**148,865**

Other inputs and assumptions for calculations

Hours per day	20
Days per week	6.5
Weeks per year	52.2
Regeneration	20%

10.3.1.2 Energy consumption in Stations

The energy consumption in stations has been estimated based on the installed capacity at stations and by applying suitable diversity factor. The table below provides the detailed estimates of the energy consumed inside the station areas.

Table 10-3 : Energy consumed in stations

KG station power	725	kW
Other stations power	490	kW
Power for all 12 stations	6,115	kW
Diversity factor	0.4	
Power for all 12 stations with diversity factor	2,446	kW
Station consumption per year	**16,598,556**	**kWh**
Station Demand kVA with 0.85 power factor	**2,878**	**kVA**

10.3.1.3 Energy consumption in Depots

The energy consumption in depots has been estimated based on the installed capacity at depots and by applying suitable diversity factor. The table below provides the detailed estimates of the energy consumed inside the depots areas.

Table 10-4 : Energy consumed in depots

Panipat Depot power when headway is 4.5 mins	973	kW
Panipat Depot power when headway is 3.5 mins	1,720	kW
Ganaur Depot throughout	567	kW
Power for both depots 2016 to 2034	1,540	kW
Power for both depots 2034 to 2041+	2,287	kW
Diversity factor	0.6	
Power for both depots 2016 to 2034 with diversity factor	924	kW
Power for both depots 2034 to 2041+ with diversity factor	1,372	kW
Total Depot consumption per year 2016 to 2034	**6,270,264**	**kWh**
Total Depot consumption per year 2034 to 2041+	**9,311,749**	**kWh**
Depot Demand kVA 2016 to 2034 with 0.85 power factor	**1,087**	**kVA**
Depot Demand kVA 2034 to 2041+ with 0.85 power factor	**1,614**	**kVA**

10.3.1.4 *Energy cost*

The energy cost at (2011 price levels) has been estimated based on the variable and fixed energy charges as mentioned below:

Variable energy charge: Rs. 4.23/kwh
Fixed energy charge – Rs 125/kVA/month

The table below provides the base energy cost in Rs Crs (at 2011 prices) calculated for all the years of operation

Table 10-5 : Base energy cost

Timeline	Total Consumption, kWh	Energy Cost per year, (Rs Cr)	Total Demand, kVA	Demand cost per year, (Rs Cr)	Total cost per year, (Rs Cr)
2016 to 2020	373,109,280	157.83	64,685	9.70	**167.53**
2021 to 2034	547,837,741	231.74	94,977	14.25	**245.98**
2035 to 2044	670,150,208	283.47	116,182	17.43	**300.90**
2044+	884,576,324	374.18	153,357	23.00	**397.18**

10.4 Maintenance Expenditure

10.4.1. Base maintenance Cost

For repair and maintenance of the RRTS assets, apart from staff, spare parts and consumables will also be used. The cost of such material which is consumed annually depends on a lot of factors such as the design of the equipment, the intensity of usage, the maintenance philosophy, the manufacturer's recommendations, renewal plans etc. The Base maintenance costs (at 2011 price levels) per annum have been estimated at a rate of 0.8% of total base capital expenditure (excluding land). Also additional maintenance costs have been considered as and when the additional asset is added to the system. This additional maintenance cost has also been assumed to be 0.8% of the additional capital expenditure incurred for the asset addition in the respective years

10.5 Total Operations and Maintenance cost

Total Operations and Maintenance cost has been calculated based on the following escalation rates:

Table 10-6 : Escalation rates for O&M cost

O&M cost component	Year on Year escalation rate
Manpower cost	8%
Energy cost	3%
Maintenance cost	5%

The total O&M cost considered for all the years of the project operations (FY17-FY46) is given in the table below:

Table 10-7 : Total O&M cost

Financial Year	Maintenance cost (Rs Million)	Manpower cost (Rs Million)	Energy cost (Rs Million)
FY 2017	668	652	1034
FY 2018	1356	1363	2060
FY 2019	1424	1472	2122
FY 2020	1495	1589	2186
2021	1620	1888	2251
2022	1860	2039	3405
2023	1953	2202	3507
2024	2050	2379	3612
2025	2153	2569	3721
2026	2261	3052	3832
2027	2374	3296	3947
2028	2492	3560	4066
2029	2617	3844	4188
2030	2748	4152	4313
2031	3045	4933	4443
2032	3701	5327	4576
2033	3886	5753	4713
2034	4081	6214	4855
2035	4285	6711	5000
2036	4499	7972	6300
2037	4724	8610	6489
2038	4960	9299	6684
2039	5208	10043	6884
2040	5469	10846	7091
2041	5742	12885	7304
2042	6029	13916	7523
2043	6331	15029	7748
2044	6647	16232	7981
2045	6979	17530	10851
2046	7328	20826	11176

11. PROJECT STRUCTURING AND VIABILTY

11.1 Recent Project Cases

Recent projects already commissioned and under construction have been used as a template to understand the typical project structures prevalent in the industry in India. Specific cases are set out below :

Table 11-1 : Recent Project Deals in India

Projects	GOI + GOS[3] (%)	SLW[4] (%)	Pvt. Sector	Length (km)	Project Cost	Cost /km
	(%)	(%)	(%)	km	Rs. Crore	Rs. Crore/km
DMRC Phase I	40	60	Nil	65	10,571	163
Phase 2	40	46	Nil	124.3	18,894	152
Phase 3 (option 1 & 2)	50+6	(int. 14) 40	Nil	69.6	21,161	304
	40+6	(int. 4) 50	Nil			
Airport Rail link, Delhi	54	Nil	46	22.7	3,869	170
Bangalore	55	45	Nil	33	6,395	194
Chennai	40.8	59.2	Nil	45	1,460	324
Kolkata	55	45	Nil	13.8	4,676	339
Mumbai L1	28.1	Nil	71.9	11	2,356	214
Mumbai L2	19.8	Nil	80.9	32	8,250	258

11.2 Role of State Government

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

11.2.1 Role of NCRPB

We understand that NCRPB has been instrumental in signing of MoUs with various states government, besides Ministry of Urban Development, Govt. of India (MoUD)

[3] Respective state government

[4] Soft Loan Provided by a Multi-lateral agency

and Ministry of Railways for making equity contribution to the RRTS project. Further, equity contributions are expected to be made in a company referred to as NCR Transport Company or say ("NCRTC") for the purpose of this report.

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

Table 11-2 : NCRTC Shareholding Pattern

Sl. No.	Name of the Entity	Percentage (%)
7.	MoUD, Govt. of India + NCRPB	25
8.	Ministry of Railways + Govt. of India	25
9.	Govt. of National Territory of Delhi	12.5
10.	State Govt. of Uttar Pradesh	12.5
11.	State Govt. of Haryana	12.5
12.	State Govt. of Rajasthan	12.5
	Total	**100**

11.2.2 NCRTC SPV for Panipat Delhi Structure

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

Table 11-3 : Equity Contribution Structure of Delhi – Sonepat - Panipat Project

Sl. No.	Name of Entity	Percentage (%)
4.	MoUD, Govt. of India + NCRPB	25
5.	Ministry of Railways + Govt. of India	25
6.	Govt. of National Territory of Delhi, State Govt. of Haryana	50
	Total	**100**

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

d) In terms of route length

Sr. No	States	Route Length	% Share in total project	% Share in 50%
		Km	%	%
1	Delhi	28.5	25.6%	12.8%
2	Haryana	88.7	74.4%	37.2%
	Total	**111.2**	**100%**	**50%**

e) In terms of investment

Sr. No	States	Base Cost in terms of Investment	% Share in total project	% Share in 50%
		Rs. Crores	%	%
1	Delhi	3202	21.9%	10.95%
2	Haryana	11435	78.1%	39.05%
	Total	**14638**	**100%**	**50%**

Note: Base cost is based on base price level which includes land cost and excludes taxes and duties.

Share of base project cost between states have been prepared based on prorate basis using route length as given in table above. In case of share of project cost based on investment, common facilities such as depot, land for depot, singaling & telecom, permanent way, R&R rolling stock and Miscellaneous works have been taken on prorate basis and station buildings, E&M works, civil, alignment and formation and etc have been taken on actual basis.

f) In terms of shareholding in the holding company

Sr. No	States	Share in NCRTC
		%
1	Delhi	12.5%
2	Haryana	12.5%
	Total	**25%**

This leaves 25% balance to be picked up by these state governments or any other entity.

11.3 Role of Lenders

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

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

11.4 Role of Private Sector

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

DIMTS has carried out analysis for structuring the project under the PPP frame work, wherein the project can be developed under a suitable PPP frame work. The total life cycle investment in the project is Rs 18790 Million.

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

11.5 Role Division Between Private Sector and Government or say NCRTC

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

Table 11-4 : Project Components – Government vs Private Sector

Item	Description	Total (Rs. Crore)	Government Sector	Private Sector
1.0	Land	3114	3114	
2.0	Civil works, Alignment and formation	3319	3319	
3.0	Station Building	1472	265	1207
4.0	E&M Works	339	72	267
5.0	Depot-cum-Workshop	206	109	97
6.0	Permanent Way	722	722	
7.0	Traction & Power Supply incl. OHE, ASS etc.	844	844	
8.0	Signalling and Telecom.	840		840
9.0	Automatic fare collection	56		56

10.0	R & R	56	56	
11.0	Misc. Works	177	177	
12.0	Rolling Stock	2142		2142
13.0	Miscellaneous Items	138		138
14.0	General Charges and contingency	1213	726	487
15.0	**Total**	**14638**	**9404**	**5234**
	In % terms			
	% of Initial Investment		**64%**	**36%**
	% of Total Lifecycle Investment		**50%**	**50%**

From the above analysis we suggest that about 64% of the initial construction cost would need to be contributed by the government or multilateral financial institutions. It would be prudent to, therefore split the project to deliver optimum project structuring wherein a government entity could raise fund from Financial Institutions and its own sources with about 36% of project cost from private sector investment.

11.6 Project Structure

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

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

c) RRTS Delhi-Panipat Infrastructure Limited (“DP Infraco”)
d) RRTS Delhi-Panipat Rolling stock Limited (“DP Rollco”)

11.6.1 DP Infraco

DP Infraco can be responsible for undertaking project activities as set out in table above marked as Government Sector in the Table in previous section.

The share holders of DP Infraco could be as set out below:

Table 11-5 : Shareholding of DP Infraco

Sl. No.	Name of Entity
•	MoUD, Govt. of India + NCRPB
•	Ministry of Railways + Govt. of India
•	Govt. of National Territory of Delhi, State Govt. of Haryana

DP Infraco could take up implementation of earmarked project activities from capitalization provided by the various government entities such as the central government and the state governments. Further, the DP Infraco could borrow money from multi-lateral financial institutions with suitable government guarantees, since multi-lateral financial institutions typically request for such guarantees as well as the fact that they would find it more convenient to fund a 100% government owned company as compared to a company with private sector majority holding.

The revenue of DP Infraco would be primarily from cess from ToD areas. In order to ensure high level of transparency in the transaction of these projects in long term of nature, it is suggested that specific benefits from ToD arising in the project not accrue to DPRollco.

The funds borrowed from multi lateral financial institutions could be paid through revenues collected as cess from ToD areas. The equity holders could keep surplus from ToD cess plus interest earned after adjustment towards loan repayment to lenders to the DP Infraco. Dividends and surplus retained by DP infraco can be paid back to NCRTC for development of additional projects in the future.

11.6.2 DP Rollco

DP Rollco can be responsible for undertaking project activities as set out in table above marked as Private Sector in the Table in previous section.

Revenue from DP Rollco shall be primarily fare box revenue, revenue from rentals at stations and commercial development at the stations and adjacent area and advertisement etc. DP Rollco will be required to undertake initial capital investment on rolling stock, signaling and elevated stations above ground.

Besides the initial investment DP Rollco shall required taking up of all operation and maintenance cost as well as making additional investments and replacements of equipment required from time to time.

In order to obtain a reasonable level of control, it is suggested that 10% of DP Rollco is held by DP Infraco with atleast with 2-3 Directors from equity holder from DP Infraco.

11.7 Funding pattern

Following the project structure as suggested above, the actual funding required upto project commissioning for the project considering the central and state govt taxes, escalation in capital cost during construction period, IDC and margin money is presented in table below:

Table 11-6 : Total Investment breakup (Capital cost including taxes, escalation, IDC and margin money)

Sl. No.	Name of Entity	Investment Based on Length		Contribution Based on Initial Investment	
		%	Rs. Crores	%	Rs. Crores
	Investments by DP Infraco				
1.	MoUD, Govt. of India + NCRPB	5.9%	1,109	5.9%	1,109
2.	Ministry of Railways + Govt. of India	5.9%	1,109	5.9%	1,109
3	Govt. of National Territory of Delhi	3.0%	568	2.6%	485
4	State Govt. of Haryana	8.8%	1,650	9.2%	1,733
5	**Total by DP Infraco**	**23.7%**	**4,436**	**23.7%**	**4,436**
6	Soft Loan	40.1%	7,517	40.1%	7,517
	Investments by DP Rollco				
7	DP Rollco	36.3%	6,801	36.3%	6,801
8	**Total investment**	**100%**	**18,755**	**100%**	**18,755**

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

In the realistic scenario in which the PPP bidding can be done, the investment between DP Infraco and DP Rollco can be divided as follows.

Name of Entity	%	Rs. Crores
DP Infraco	30%	5638
Soft Loan	40%	7482
DP Rollco (Private sector)	30%	5644
Total	**100%**	**18764***

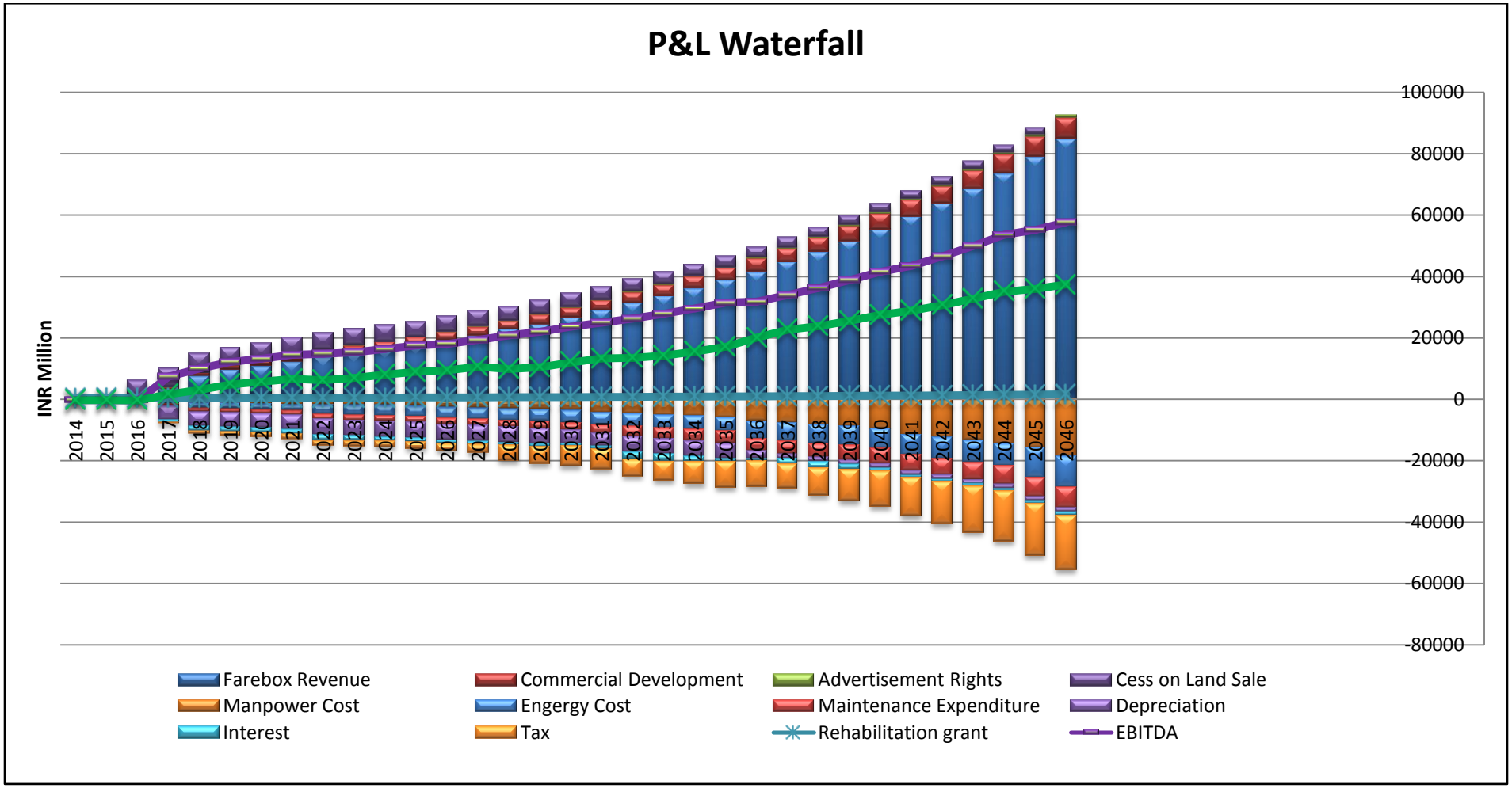
*The difference in total cost from the previous table is attributable to IDC

11.8 Profit and loss account

The project profit and loss statement for the project is presented below:

Table 11-7 : Profit and Loss statement synopsis for key years

P&L Statement (Rs Mil)	FY18	FY22	FY27	FY32	FY37	FY42	FY46
Revenue							
Fare box revenue	**7575**	**13929**	**20882**	**31307**	**44704**	**63835**	**84883**
Revenue from commercial development	987	2101	2682	3422	4368	5575	6776
Revenues from Advertisment Rights	76	139	209	313	447	638	849
Other Revenue (from TOD Cess)	6075	5670	4860	4232	3275	2534	2064
Total Revenue	***14713***	***21839***	***28633***	***39275***	***52794***	***72582***	***94572***
Expenses							
Maintenance cost	1356	1860	2374	3701	4724	6029	7328
Manpower cost	1363	2039	3296	5327	8610	13916	20826
power cost	2060	3405	3947	4576	6489	7523	11176
Rehabilitation Grant	438	533	680	868	1107	1413	1718
Total operating expenses	***5217***	***7837***	***10297***	***14472***	***20931***	***28881***	***41048***
EBITDA	9496	14003	18336	24803	31864	43700	53523
Depreciation	4597	5087	5087	5027	1424	1424	1422
EBIT	4898	8915	13249	19776	30439	42276	52102
Interest on long term loan	*1428*	*1693*	*752*	*1894*	*1605*	*0*	*0*
Interest on short term loan	*142*	*240*	*313*	*429*	*566*	*776*	*994*
PBT	3328	6983	12184	17454	28269	41500	51107
Tax	666	1,397	2,438	4,944	7,005	12,747	16,420
PAT	**2662**	**5586**	**9746**	**12510**	**21264**	**28753**	**34688**


P&L Waterfall
INR Million
100000
80000
60000
40000
20000
0
-20000
-40000
-60000
-80000
2014
2015
2016
2017
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2041
2042
2043
2044
2045
2046
Farebox Revenue
Commercial Development
Advertisement Rights
Cess on Land Sale
Manpower Cost
Engergy Cost
Maintenance Expenditure
Depreciation
Interest
Tax
Rehabilitation grant
EBITDA

11.9 Cash flow and return for the project

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

The project IRR and Equity IRR for the project are as follows:

- Project IRR (Post Tax) 5.78%
- Project IRR (Pre Tax) 7.44%
- Equity IRR (for DP Rollco) 16.08%

The table below presents for the key years the cash inflow and outflow for the project and the project and Equity IRRs

Table 11-8 : Project Cash flow for estimation of Project IRR (Post Tax)

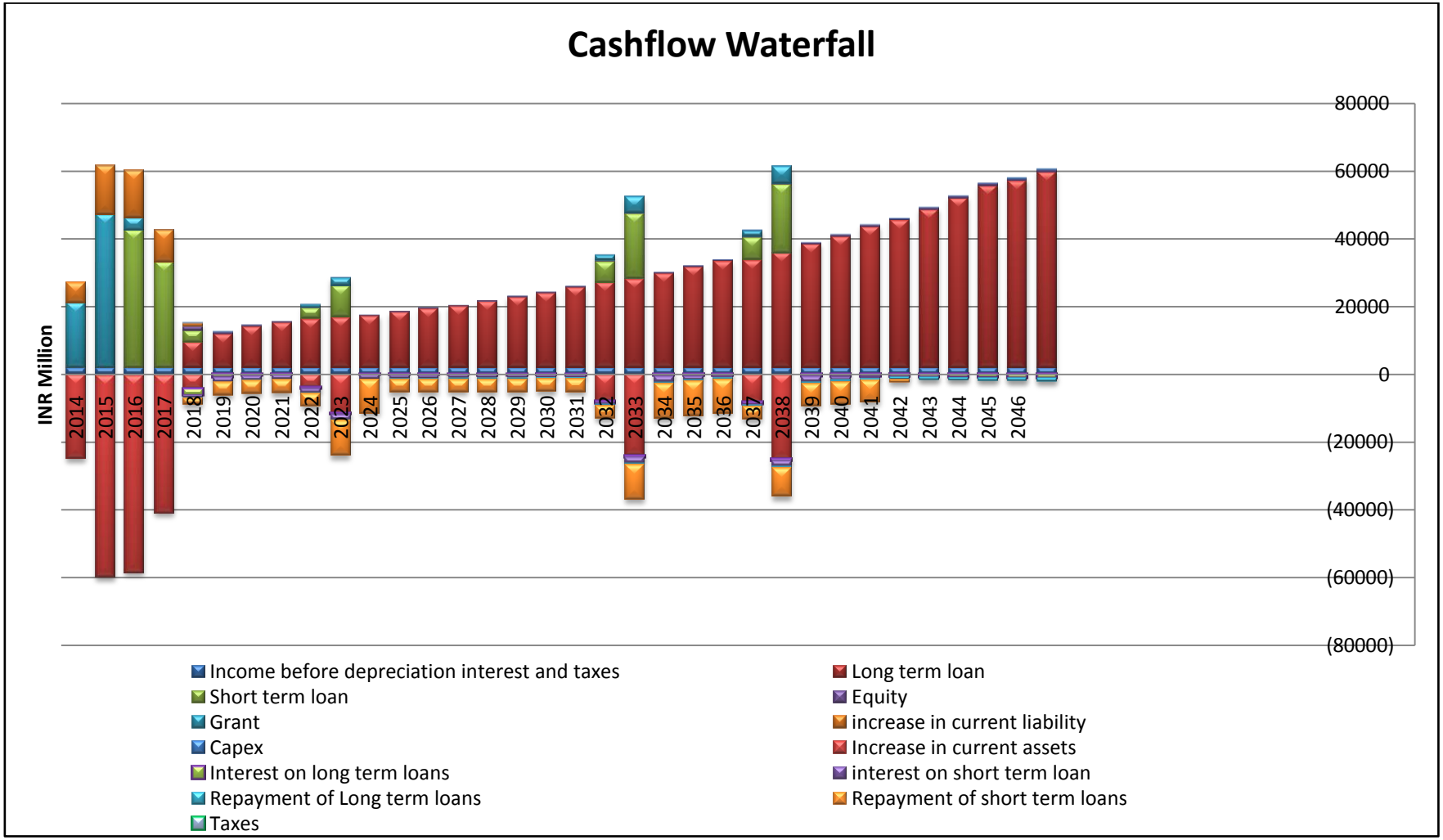
Particulars (All figures in Rs Mil)	FY13	FY14	FY15	FY16	FY17	FY21	FY22	FY27	FY32	FY37	FY42	FY46
Inflow												
PAT	0	-360	-379	-397	1383	6098	5586	9746	12510	21264	28753	34688
Interest	0	0	0	0	801	1464	1932	1065	2323	2171	776	994
Depreciation	0	0	0	0	4597	4720	5087	5087	5027	1424	1424	1422
Total Inflow	**0**	**-360**	**-379**	**-397**	**6781**	**12282**	**12605**	**15898**	**19859**	**24859**	**30954**	**37104**
Outflow												
Capital Investment	-24986	-59527	-58152	-40558	-4328	-3862	-11586	0	-24015	-25024	0	0
IDC	0	0	333	1246	733	0	0	0	0	0	0	0
Total Outflow	-24986	-59527	-57819	-39311	-3595	-3862	-11586	0	-24015	-25024	0	0
Net flow	**-24986**	**-59887**	**-58198**	**-39709**	**3186**	**8420**	**1019**	**15898**	**-4155**	**-165**	**30954**	**37104**
Project IRR (Post Tax)	**5.78%**											

Table 11-9 : Project Cash flow for estimation of Project IRR (Pre Tax)

Inflow	FY13	FY14	FY15	FY16	FY17	FY21	FY22	FY27	FY32	FY37	FY42	FY46
PBT	0	-360	-379	-397	1729	7623	6983	12184	17454	28269	41500	51107
Interest	0	0	0	0	801	1464	1932	1065	2323	2171	776	994
Depreciation	0	0	0	0	4597	4720	5087	5087	5027	1424	1424	1422
Total Inflow	**0**	**-360**	**-379**	**-397**	**7127**	**13807**	**14003**	**18336**	**24803**	**31864**	**43700**	**53523**
Outflow												
Capital Investment	-24986	-59527	-58152	-40558	-4328	-3862	-11586	0	-24015	-25024	0	0
IDC	0	0	333	1246	733	0	0	0	0	0	0	0
Total Outflow	**-24986**	**-59527**	**-57819**	**-39311**	**-3595**	**-3862**	**-11586**	**0**	**-24015**	**-25024**	**0**	**0**
Net flow	**-24986**	**-59887**	**-58198**	**-39709**	**3532**	**9945**	**2417**	**18336**	**788**	**6840**	**43700**	**53523**
Project IRR (Pre Tax)	**7.44%**											

Table 11-10 : Project Cash flow for estimation of Equity IRR (for DP Rollco)

Particulars (All figures in Rs Mil)	FY13	FY14	FY15	FY16	FY17	FY21	FY22	FY27	FY32	FY37	FY42	FY46
Inflow												
PAT	0	-360	-379	-397	1383	6098	5586	9746	12510	21264	28753	34688
Depreciation	0	0	0	0	4597	4720	5087	5087	5027	1424	1424	1422
Principal Repayment	0	0	0	0	1879	3759	10225	3759	10225	8346	0	0
Total Inflow	**0**	**-360**	**-379**	**-397**	**7860**	**14576**	**20898**	**18592**	**27762**	**31034**	**30178**	**36109**
Outflow												
Equity outflow	-18989	-45240	-3784	0	0	-772	-2317	0	-4803	-5005	0	0
Total Outflow	**-18989**	**-45240**	**-3784**	**0**	**0**	**-772**	**-2317**	**0**	**-4803**	**-5005**	**0**	**0**
Net flow	**-18989**	**-45601**	**-4163**	**-397**	**7860**	**13804**	**18581**	**18592**	**22959**	**26029**	**30178**	**36109**
Equity IRR	**16.08%**											


Cashflow Waterfall
INR Million
80000
60000
40000
20000
0
(20000)
(40000)
(60000)
(80000)
2014
2015
2016
2017
2018
2019
2020
2021
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2042
2043
2044
2045
2046
Income before depreciation interest and taxes
Short term loan
Grant
Capex
Interest on long term loans
Repayment of Long term loans
Taxes
Long term loan
Equity
increase in current liability
Increase in current assets
interest on short term loan
Repayment of short term loans

11.10 Debt service and DSCR

The debt servicing of the soft loan can be under taken from the development cess on TOD levied on sale of built up area as described in the Revenue estimation chapter.
The table below provides the Net Present Value (@10% discount factor) of the revenues generated from TOD cess and principal and interest repayment of the soft loan from the multilateral agencies

Table 11-11 : Debt servicing

Cess on TOD	Rs Millions NPV@10%	Remarks
Revenue from Cess		
During construction period	10,231	The cess collected during construction phase can be used to fund the equity contribution by the Govt for the project
During Operations period	26,956	The cess collected during the operations period can be utilized for servicing the soft loan
Debt Servicing		
Principal Repayment	17,242	
Interest Repayment	4,484	
Total Debt servicing	21,726	
Surplus after debt servicing	5229	Surplus funds after debt servicing may be distributed among the shareholders

The table below provides details of Debt service coverage ratio for the project

Table 11-12 : DSCR for key years

All figs in Rs Mil	FY17	FY21	FY22	FY23	FY27	FY32	FY37	FY42	FY46
PAT	1383	6098	5586	6272	9746	12510	21264	28753	34688
Depreciation	4597	4720	5087	5087	5087	5027	1424	1424	1422
Interest	801	1464	1932	1577	1065	2323	2171	776	994
Total Cash Available During Loan Tenor	6781	12282	12605	12936	15898	19859	24859	30954	37104
Total Debt	2680	5223	12158	11228	4823	12548	10517	776	994
Contingent Equity reqd. before Debt servicing									
Cash Available for Debt Servicing	6781	12282	12605	12936	15898	19859	24859	30954	37104
Cash Available Post Debt Service	4101	7059	448	1708	11075	7311	14342	30178	36109

DSCR	2.53	2.35	1.04	1.15	3.30	1.58	2.36	39.89	37.31
Min DSCR	**1.04**								
No. of years when DSCR<1.25	**2**								
Average DSCR	**3.42**								

11.11 Scenario Analysis

A comprehensive scenario analysis has been conducted to understand the impact of variation in various revenue and cost elements on the feasibility of the project. Project IRR, Equity IRR and DSCR have been calculated to understand the project feasibility under various scenarios

11.11.1. Defining Scenarios

Following scenarios have been generated in the financial model and IRR's and DSCR have been calculated for each of the scenario. It may be noted that each scenario is independent in its own and all scenarios are mutually exclusive. This analysis is for comparison of the base case with individual scenarios

- Scenario 1 – Waiver in central and State taxes on Capital cost
- Scenario 2 – Variation in capital cost by +10% or -10%
- Scenario 3 – Variation in farebox revenue by +10% or -10%
- Scenario 4 – Variation in Other revenue by +10% or -10%
- Scenario 5 – Variation in O&M cost by +10% or -10%
- Scenario 6 – Long term loan rate of interest 10% instead of 2%

11.11.2. Scenario Results

The table below presents the results of running the above scenarios in the financial model

Table 11-13 : Scenario Analysis

Sr	Scenario	Variation	Project IRR (Post Tax)	Equity IRR	Average DCSR	Minimum DSCR
	BASE CASE		**5.78%**	**16.08%**	**3.44**	**1.04**
1	Waiver of Central taxes		6.44%	16.61%	3.8	1.18
	Waiver of Central and State taxes		6.81%	17.00%	4.00	1.24
2	Capital cost	+10%	5.16%	15.30%	3.21	0.98
		-10%	6.50%	16.98%	3.64	1.11
3	Fare box revenue	+10%	6.54%	16.79%	3.81	1.13
		-10%	4.94%	15.31%	3.04	0.95
4	Other revenues	+10%	6.01%	16.42%	3.50	1.09
		-10%	5.54%	15.71%	3.34	0.99
5	O&M cost	+10%	5.38%	15.67%	3.24	0.99

		-10%	6.15%	16.46%	3.6	1.09
6	Long term loan Interest rate 10%		6.17%	13.68%	2.58	0.79

11.12 Total Lifecycle Investment

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

Table 11-14 : Total lifecycle investment by Government vis a vis private sector partner at 2011 price levels

Item	Description	Total (Rs. Crore)	Govt (Rs Crs)	Pvt. (Rs Crs)
1.0	Land	3114	3114	
2.0	Civil works, Alignment and formation	3319	3319	
3.0	Station Building	1472	265	1207
4.0	E&M Works	339	72	267
5.0	Depot-cum-Workshop	206	109	97
6.0	Permanent Way	722	722	
7.0	Traction & Power Supply incl. OHE, ASS etc.	844	844	
8.0	Signalling and Telecom.	840		840
9.0	Automatic fare collection	56		56
10.0	R & R	56	56	
11.0	Misc. Works	177	177	
12.0	Rolling Stock	2142		2142
13.0	Miscellaneous Items	138		138
14.0	General Charges and contingency	1213	726	487
15.0	**Total**	**14638**	**9404**	**5234**
	% component on initial construction cost		**64%**	**36%**
16	IDC and Margin money	270		270
17	Future investment	2512		2512
18	Replacement cost	1370		1370
19	**Total Lifecycle investment**	**18790**	**9404**	**9386**
	% component on total lifecycle cost		**50.05%**	**49.95%**

11.13 Recommendations and Way Forward

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

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

For this purpose the 10% stake in DPRollco by DPInfraco assumes great significance since DPInfraco will bid out the project, based on the valuation of equity of DPRollco. This would be by way of positive or negative valuation for nominal 10% of DPRollco by the Concessionaire who shall have the controlling stake in the DPRollco.

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

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

A. Formation of DPInfraco with equity share holding with percentage as suggested in the report
B. Setting up of DPRollco with minimum capital charges are required in terms of company law
C. Commencement of negotiation with financial institution and Government of India for obtaining soft loan.
D. Selection of suitable transaction advisory:
    i. Commencement dialogue with Government
    ii. Commencement with bidding process
E. Inviting state governments to obtain necessary equity stake in the Infraco.
F. Declaration of Transit Oriented Development zones
G. Preparation of Development Plans based on ToD Areas identified by this report within a timeframe say 3 months of release of this report
H. Legislation for collection of cess from ToD areas
I. Land acquisition where required for the project infrastructure area
J. Identification and marking of alignment on the green belt in Haryana

12. ECONOMIC EVALUATION

12.1 Approach

Economic viability of the proposed RRTS project has been assessed within the broad framework of "Cost-Benefit Analysis", generally used for appraisal of public investment projects. In economic evaluation, benefits are computed for the economy as a whole rather than for an individual entity who has made the investment. In case of financial analysis the profits become the major factor for evaluation whereas in economic analysis the benefits to the economy are the main criteria for evaluation.

The economic analysis involves comparison of project costs and benefits in economic terms under the "with" and "without" project conditions and determining the Economic Internal Rate of Return (EIRR) of the project using discounted cash flow technique. This shows the return which the society could expect from the proposed investment during the project life, i.e. analysis period. The EIRR is then compared with the accounting rate of return considered as the cut-off point for undertaking the investment by the Government of India and international funding agencies like the World Bank and the Asian Development Bank (ADB).

The main steps followed are:

i) Estimation of capital and maintenance costs at economic prices, along with the capital cost phasing

ii) Estimation of economic benefits

iii) Comparison of annual streams of costs with benefits and estimation of EIRR

The project is further subjected to sensitivity analysis by assessing the effects of adverse changes in the key variables on the base EIRR. This helps to gauge the economic strength of the project to withstand future risks and uncertainties..

12.2 The Improvement

Description of economic benefits and costs of the Delhi –Sonepat Panipat RRTS requires the identification of the changes brought out by it in the transport sector of the economy. Most importantly, RRTS contributes to the diversion of a high proportion of current private traffic from road to RRT and serves part of the growing passenger traffic demand in NCR. As a result, there will be a reduction in the number of buses, passenger cars and other vehicles carrying passengers on NCR roads. There will be savings in travel time for passengers traveling by RRT due to higher speed and residual traffic left on road will also be benefited due to reduced congestion. The RRTS will also bring about a reduction in air pollution because of the substitution of electricity for petrol and diesel and enhances safety on the roads. There will also be a reduction in the number of accidents on the roads.

Investment in the RRT could result in the reduction of government investments on road developments and buses as also in the private sector investment on buses, cars and other vehicles carrying passengers. There will be reductions in motor vehicles operation and maintenance charges to both the government and the private sector.

In addition, there will be health and other environmental benefits to the public due to reduced pollution from the transport sector of NCR. Land and house property owners gain from the increased valuation of house property prices due to the RRT. While some of the above benefits are quantifiable, others are difficult to measure. For the proposed project, benefits from following were assessed:

- Savings in Fuel Consumption
- Savings in Vehicle Capital Costs
- Savings due to reduced Environmental Pollution
- Savings in Travel Time
- Savings in Road Construction costs

In addition the items quantified above, the community will be benefited by following items which are difficult to quantify. These are listed below;

- Health Benefits.
- Savings due to fewer accidents
- Savings in vehicular operating costs due to the decongestion effect on residual traffic
- Land price increase

12.3 Project Cost and Scheduling

The cost of the proposed RRTS infrastructure project consists of two main components:

- Capital cost of construction of RRTS
- Operation and Maintenance cost

Economic analysis requires the conversion of financial costs into economic costs to take care of distortions in prices due to market imperfections. Taxes and duties are removed from financial prices, as these are not real costs to the economy, but are only transfer payments.

All financial costs have been converted into economic costs, which are net of taxes and duties, by applying the standard conversion factor of 0.9.

12.4 Capital Cost and it's Phasing

The capital cost of the project in financial terms is estimated at Rs146377 Million (2011 prices) . The project cost is to be incurred over four years, with as discussed in table 7.2 The facilities will be operational from 2016. The economic cost of the project works out by applying the conversion factor of 0.9 to financial costs.

12.5 Operations and maintenance cost

The operation and maintenance (O&M) cost involves energy cost, staff cost and other operation and maintenance of running RRTS and related facilities. The cost of

operation and maintenance is estimated and described in the chapter of Estimation of Operations and Maintenance cost

The operation and maintenance cost is also converted into economic costs by applying a factor of 0.90. The operation and maintenance cost in financial terms is Rs3434Million. The corresponding cost in economic terms is 3087Million.

12.6 Project benefits

The commissioning of the proposed RRTS project is expected to result in both direct and indirect benefits to the users. The present analysis covers quantification of direct benefits in terms of savings in time, VOC/fuel, capital cost of cars, highway construction. Benefits due to improved environmental conditions are also quantified using rapid techniques.

12.6.1. Time Savings

In order to work out time savings, the speeds for different vehicles have been calculated from surveys. The RRTS speeds were determined from simulation done as part of operation plan. The time savings have been worked out as the difference of travel time under “with and “without” project situations. The savings of travel time of passengers traveling by the RRTS instead of by road are calculated as the product of the number of passengers traveled daily and the time saved on the average passenger trip lead on the corridor.

The average Value of Time per person is arrived based on traffic surveys conducted for project. The average VOT rates adopted are Rs. 71.4 per hour. Passenger time saving per annum for RRTS is then calculated as the product of daily passengers carried, time saved on average lead on an annual basis and the value of time of RRTS passengers. Benefits to residual vehicles are not considered in present analysis. The total time savings per year are presented in table below

Table 12-1 : Economic benefits – Time savings

Year	Time Saving (Rs Cr/Year)
2016	441.39
2021	828.38
2031	1179.72
2041	1961.53

12.6.2. Fuel Cost Savings

There are savings in fuel consumption due to the diversion of a part of the road traffic to RRTS and reduced congestion to vehicles still operating on the roads. Fuel saved due to traffic diverted to the RRTS is estimated given the estimates of diverted traffic and the distance travelled and fuel consumption norms of different vehicles. The total fuel savings based on 2011 price levels is presented below

Table 12-2 : Economic benefits – Fuel cost savings

Items	Units	2016	2021	2031	2041
Fuel saved per year	lts ('000)	107267	155637	221647	279691
Cost of fuel saved per year	Rs Crs	658	934	1330	1717

12.6.3. Saving in road construction cost

Due to the lesser number of vehicles on road due to RRTS, lesser road capacity will be required. This will results in savings of highway construction cost. To estimate savings, total additional express highway lanes required in "without RRTS situation" were calculated and multiplied with average construction cost of Rs 30 crore/km for 2+2 lane express highway for 90 km length. The land acquisition cost was estimated by assuming 60 m ROW requirement for 90 km stretch land acquisition. The savings are as under:

Table 12-3 : Economic benefits – Savings in road construction cost

Year	Fuel Cost Savings (Rs Crs/year)	Time Cost Savings (Rs Crs/year)	Highway Construction cost savings (Rs Crs)	Land acquisition cost Savings (Rs Crs)
2016	456	441.39	3000	4800
2021	722	828.38	1500	0
2031	1045	1179.72	1500	0
2041	1419	1961.53	3000	0

12.6.4. Environmental benefits

Fewer vehicles and the decongestion for the residual traffic on influence area roads due to RRTS could lead to reduced air pollution. An estimate of the pollution reduction by a vehicle in this context could be obtained by multiplying the distance saved by the relevant emission coefficient for different pollutants for each category of vehicle. The emission coefficients for different vehicles are given in table below. Estimates of reduction in distance traveled every day due to the lesser vehicles on the road is estimated by assuming average vehicle travel of 55 km for cars, 25 kms for 2 wheelers and 200 km for buses . The monetary value of these pollution loads are estimated using the estimates of prices of pollutants made in some recent studies in India which are reported in the same table

Table 12-4 : Pollutant by vehicle type (kg/km)

Pollutant	car	2wheel	Bus	Cost (Rs)
PM	0.03	0.075	0.05	4777
NOX	0.2	0.3	0.87	6724
HC	0.075	0.7	2.75	502
CO	0.08	2.2	0.66	448

Table 12-5 : Economic benefits: Savings due to reduction in pollutants

Year	Cost Savings (Cr)
2016	124.8
2021	181.1

2031	257.9
2041	325.5

12.6.5. Vehicle capital cost savings

The number of vehicles going off the road due to the introduction of RRTS was estimated by determining the shift of private vehicle passengers and bus passengers. Based on average occupancy of various vehicle types, passenger data was converted into vehicles for analysis purpose. This data was projected as per the transport demand forecasts conducted for the project.

The total capital cost saving due to fewer vehicles on the road is estimated and presented in Table below:

Table 12-6 : Economic benefits: Vehicle capital cost saving

Year	Cost Saving (Cr)
2016	1936
2021	873
2031	1191
2041	1047
Total	5047

12.7 Economic Internal Rate of Return (EIRR)

The benefits vehicle operating cost savings, time savings due to increased speed and environmental benefits with improved environment are added together to get the total savings. The net cash flow statements are presented in table below**.** The rate of return considered desirable for the transport infrastructure project in India is 12 percent. As EIRR of proposed RRTS facility is 22.31 %, which is above 12 percent cut-off rate, the project is economically viable. EIRR is further tested for case excluding savings resulting due to value of time. For this case project is able to achieve EIRR of 16.69% making it economically viable.

Table 12-7 : Economic benefits: EIRR and cashflow

Year	Costs (Rs Crs)		Benefits (Rs Crs)						Net Benefit
	Capital Costs	O&M Cost	Fuel Cost Savings	Time Savings	Vehicle Capital Cost Saving	Environmental Benefits	Highway cost Savings	Total	Rs Crs
2013	2031.3	308.7							-2340
2014	4633.2	308.7							-4942
2015	3878.1	308.7							-4187
2016	2563.2	308.7	658	441	1936	125	7815	10975	8103
2017	276.3	308.7	706	473	0	134	15	1328	743
2018		308.7	757	508	0	144	15	1424	1115
2019		308.7	812	545	0	154	15	1526	1217
2020		308.7	871	584	0	165	15	1635	1327

2021		308.7	934	828	873	181	4575	7392	7083
2022		308.7	968	858	0	188	30	2044	1735
2023		308.7	1003	889	0	194	30	2116	1807
2024		308.7	1039	921	0	201	30	2191	1883
2025		308.7	1076	954	0	209	30	2269	1960
2026		308.7	1115	989	0	216	180	2500	2191
2027		308.7	1155	1024	0	224	30	2433	2124
2028		308.7	1197	1061	0	232	30	2520	2211
2029		308.7	1240	1099	0	240	30	2609	2300
2030		308.7	1284	1139	0	249	30	2702	2393
2031		308.7	1330	1180	1191	258	1680	5639	5331
2032		308.7	1365	1210	0	265	45	2885	2576
2033		308.7	1400	1241	0	271	45	2958	2649
2034		308.7	1436	1273	0	278	45	3033	2724
2035		308.7	1473	1306	0	286	45	3110	2802
2036		308.7	1511	1340	0	293	180	3324	3016
2037		308.7	1550	1375	0	301	45	3271	2962
2038		308.7	1590	1410	0	308	45	3354	3045
2039		308.7	1631	1447	0	316	45	3439	3131
2040		308.7	1674	1484	0	324	45	3527	3218
2041		308.7	1717	1962	1047	325	45	5096	4788
EIRR	**22.31%**								

12.8 Sensitivity Analysis

The robustness of the project's viability is further demonstrated by the sensitivity analysis. Because of the uncertainties pertaining to traffic forecasts and critical parameters relating to cost and benefits, a sensitivity analysis was carried out to test the economic strength of the project. The variations in the following parameters have been examined, considering them to be on the conservative side:

- Increase in cost by 10 percent
- Decrease in benefits by 10 percent
- Increase in cost by 10 percent and decrease in benefits by 10 percent

The results of the sensitivity analysis are presented in the table below

Table 12-8 : Economic benefits: EIRR sensitivity analysis

Case	Economic Internal Rate of Return
10% increase in costs	19.71%
10% Decrease in benefits	19.45%
10% increase in costs and 10% decrease in benefits	17.14%

Appendix 2.1: Fleet Expansion Analysis

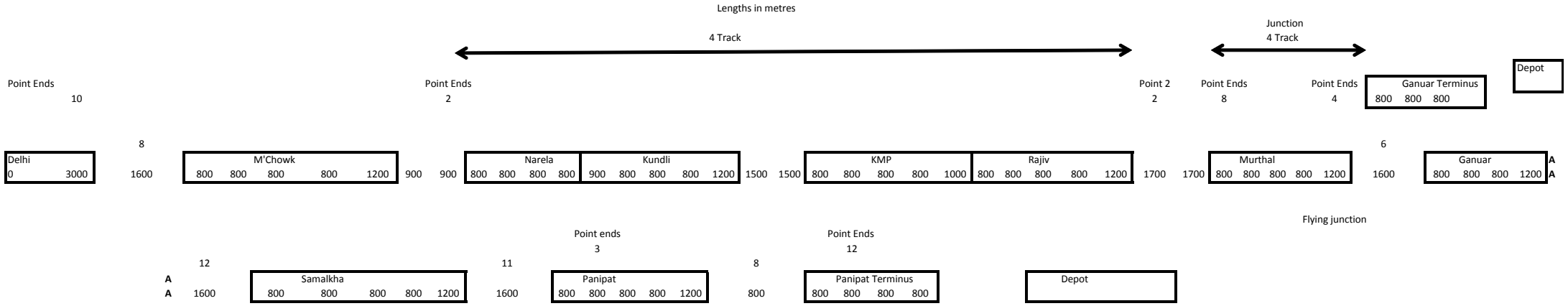
Analysis Using 3, 6, and 9 car sets (Fixed Formation)

		Purchasing Profile					Train Configuration									
Year	**Headway**	**3-car**	**6-car**	**9-car**	**Cars**	**Fleet**	**2x3**	**1x6**	**3x3**	**4x3**	**1x3 + 1x6**	**2x3 + 1x6**	**1x9**	**1x3 + 1x9**	**Trains**	**Note**
2021	4.5	34	17	0	204	204	17	17	0	0	0	0	0	0	34	6-car trains. Allows 3-car sets to be run off-peak to maintain frequency
Increment	4.5	1	0	11	102	306	0	0	6	0	17	0	11	0	34	9-car trains. Allows 6-car sets to be run off-peak @4.5 minutes.
2041	3.5	0	0	10	90	396	0	0	6	0	17	0	21	0	44	9-car trains. Provides 34No 6-car sets to run off-peak @4.5 minutes
2041+	3.5	44	0	0	132	528	0	0	0	6	0	17	0	21	44	12-car trains. Allows 9-car or 6-car off-peak service @3.5 minutes
		79	17	21												

Analysis Using 3, and 6 car sets (Fixed Formation)

		Purchasing Profile					Train Configuration									
Year	**Headway**	**3-car**	**6-car**	**9-car**	**Cars**	**Fleet**	**2x3**	**1x6**	**3x3**	**4x3**	**1x3 + 1x6**	**2x3 + 1x6**	**1x9**	**1x3 + 1x9**	**Trains**	**Note**
2021	4.5	34	17	0	204	204	17	17	0	0	0	0	0	0	34	6-car trains. Allows 3-car sets to be run off-peak to maintain frequency
Increment	4.5	12	11	0	102	306	0	0	6	0	28	0	0	0	34	9-car trains. Allows 6-car sets to be run off-peak @4.5 minutes.
2041	3.5	10	10	0	90	396	0	0	6	0	38	0	0	0	44	9-car trains. Allows 6-car sets to run off-peak @3.5 minutes
2041+	3.5	40	2	0	132	528	0	0	0	4	0	40	0	0	44	12-car trains. Allows 9-car or 6-car off-peak service at 3.5 minutes
		96	40													

APPENDIX 4.2: SECTIONED SCHEMATIC



Equipment Numbers	Point Ends	Axle Counters
Delhi	8	30
M'Chowk	0	14
Narela	2	20
Kundli	0	20
KMP	0	20
Rajiv	2	22
Murthal	8	40
Ganuar	0	10
Ganuar Terminus	4	10
Samalkha	0	10
Panipat	4	20
Panipat Terminus	12	24
Depot 1	30	15
Depot 2	15	10
Plain Line	0	110
	85	**375**
Control centre	**2**	
Rolling stock to fit	**30**	

Appendix 7.1 Timetabling Options

OPTION A (2021)
ALL STATIONS SERVICE

Kashmere Gate	dep	2400	0020	0040	then	0600	0605	0610	0615	0620	0625	0630	0635	0640	0645	0650	0655	then
Mukarba Chowk	dep	0012	0032	0052	at	0612	0617	0622	0627	0632	0637	0642	0647	0652	0657	0702	0707	at
Narela	arr	0017	0037	0057	the	0617	0622	0627	0632	0637	0642	0647	0652	0657	0702	0707	0712	the
	dep	0018	0038	0058	same	0618	0623	0628	0633	0638	0643	0648	0653	0658	0703	0708	0713	same
Kundi	dep	0022	0042	0102	minutes	0622	0627	0632	0637	0642	0647	0652	0657	0702	0707	0712	0717	minutes
KMP Interchange	dep	0028½	0048½	0108½	past	0628½	0633½	0638½	0643½	0648½	0653½	0658½	0703½	0708½	0713½	0718½	0723½	past
Rajiv Gandhi	arr	0032	0052	0112	each	0632	0637	0642	0647	0652	0657	0702	0707	0712	0717	0722	0727	each
	dep	0032½	0052½	0112½	hour	0632½	0637½	0642½	0647½	0652½	0657½	0702½	0707½	0712½	0717½	0722½	0727½	hour
		[1]	[1]	[1]	until	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	until
Murthal	arr	0039	0059	0119		0639	0644	0649	0654	0659	0704	0709	0714	0719	0724	0729	0734	midnight
	dep	0040	0100	0120		0640	0645	0650	0655	0700	0705	0710	0715	0720	0725	0730	0735	
Ganaur Terminus	arr						0648		0658		0708		0718		0728		0738	
Ganaur City	dep	0049	0109	0129		0649		0659		0709		0719		0729		0739		
Samalkha	dep	0055½	0115½	0135½		0655½		0705½		0715½		0725½		0735½		0745½		
Panipat	dep	0105½	0125½	0145½		0705½		0715½		0725½		0735½		0745½		0755½		
		[1½]	[1½]	[1½]		[1½]		[1½]		[1½]		[1½]		[1½]		[1½]		
IOCL Panipat	arr	0114	0134	0154		0714		0724		0734		0744		0754		0804		

IOCL Panipat	dep	2400	0020	0040	then		0600		0610		0620		0630		0640		0650	then
Panipat	dep	0007½	0027½	0047½	at		0607½		0617½		0627½		0637½		0647½		0657½	at
Samalkha	dep	0017	0037	0057	the		0617		0627		0637		0647		0657		0707	the
Ganaur City	dep	0024	0044	0104	same		0624		0634		0644		0654		0704		0714	same
		[1]	[1]	[1]	minutes		[1]		[1]		[1]		[1]		[1]		[1]	minutes
Ganaur Terminus	dep				past	0625		0635		0645		0655		0705		0715		past
Murthal	arr	0033	0053	0113	each	0628	0633	0638	0643	0648	0653	0658	0703	0708	0713	0718	0723	each
	dep	0034	0054	0114	hour	0629	0634	0639	0644	0649	0654	0659	0704	0709	0714	0719	0724	hour
Rajiv Gandhi	arr	0039½	0059½	0119½	until	0634½	0639½	0644½	0649½	0654½	0659½	0704½	0709½	0714½	0719½	0724½	0729½	until
	dep	0040	0100	0120		0635	0640	0645	0650	0655	0700	0705	0710	0715	0720	0725	0730	midnight
KMP Interchange	dep	0044½	0104½	0124½		0639½	0644½	0649½	0654½	0659½	0704½	0709½	0714½	0719½	0724½	0729½	0734½	
Kundi	dep	0050½	0110½	0130½		0645½	0650½	0655½	0700½	0705½	0710½	0715½	0720½	0725½	0730½	0735½	0740½	
Narela	arr	0054	0114	0134		0649	0654	0659	0704	0709	0714	0719	0724	0729	0734	0739	0744	
	dep	0055	0115	0135		0650	0655	0700	0705	0710	0715	0720	0725	0730	0735	0740	0745	
Mukarba Chowk	dep	0101	0121	0141		0656	0701	0706	0711	0716	0721	0726	0731	0736	0741	0746	0751	
		[1½]	[1½]	[1½]		[1½]	[1½]	[1½]	[1½]	[1½]	[1½]	[1½]	[1½]	[1½]	[1½]	[1½]	[1½]	
Kashmere Gate	arr	0114	0134	0154		0709	0714	0719	0724	0729	0734	0739	0744	0749	0754	0759	0804	

KEY: [1] Allowance for engineering work