Volume 5 | AutoBots Commercial & Economic Feasibility

AutoBots System Vs
Case of Haridwar Pod Taxi Tender

Return on Investment & Internal Rate of Return for a Typical 20 Km Bi-Directional Line System

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Under Co-Development MoU Between

EcoAutoMo Private Limited
D 113, East of Kailash, New Delhi 110065 INDIA

Foundation for Innovation & Technology Transfer
at Indian Institute of Technology,
Hauz Khas, New Delhi 110016 INDIA

Document prepared by

Tranxit Mobility Logistics Pvt Ltd
D 113, East of Kailash, New Delhi 110065 INDIA

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Contacts

Anupam Vibhuti, Director

EcoAutoMo Private Limited
D 113, East of Kailash, New Delhi 110065 INDIA
P: +91 4162 4401/2/3 M: +91 9810070013
E: anupam.vibhuti@gmail.com

Prof. Brejesh Lall, Principal Investigator on behalf of FITT at IITD

Department Of Electrical Engineering,
Indian Institute of Technology
Hauz Khas, New Delhi 110016 INDIA
P: +91-11-26591068 M: +91 98100 72895
E: brejesh@ee.iitd.ac.in

Version No| 1.1 | 15032023

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A. Understanding a Typical 20 Km Bi-Directional AutoBots System

AutoBots system design is carefully denominated to serve a group size of not more than 2 persons at a time, simply to reflect the global group size human travel requirements where globally ~85% of the times humans travel within a group size of 2 persons. And ~15% of the time the group size is more than 2.

This is reflective of the well-known statistical fact of average group size in most cities being 1.1-1.3 (for a specific trip purpose) and probability calculations of finding more than 2 persons in a travel group within the standard deviation formulation, which is less than 15%.

A vehicle with a seating capacity of more than 2 persons, runs the risk of not being able to fill up, in a system-defined time limit, before the vehicle needs to leave the boarding bay. A ride-matching algorithm can assist in the process in a linear alignment format but may not suffice in a many-to-many origins destination grid format.

1. Pod Capacity

AutoBots pod capacity is deliberately limited to 2 seats. This espouses several advantages to the system design.

- Reduction in the width of the pod means just 1.2m aerial RoW for each track, therefore system capacity can be added incrementally for the same aerial RoW provided, against a min. 4.2 m required for 4-6 seat systems.
- Reduction in pod weight load means a reduction of the depth of any beam by its 2nd power, therefore proportional reduction in CAPEX employed.
- Reduction in the size of the supporting column of any standard column by its 4th power, therefore a proportional reduction in CAPEX employed.
- No ride matching requirement for ~85% of travel groups, which otherwise is a necessity for larger seat vehicle carriers for each origin-destination pair. Ride matching results in substantially larger waiting for each passenger. (E-rickshaws / Vikram phenomenon even along the same route)
- With lesser wastage of available capacity (forced time-limited departures even if the pod is not full) a higher capacity utilization (~65-70%) can be expected. In the case of 4-6 seat pods ~45% capacity utilization has been predicted[1].
- Lower power requirements for acceleration and decelerations, therefore a reduction in the power ratings of each power train, therefore a reduction in CAPEX.

2. Satisfying Capacity Requirements

The AutoBots system by design employs several strategies to increase its line or grid system capacity

[1] Development of "Personal Rapid Transit (PRT) System at Amritsar (Punjab) on Public Private Partnership format through Swiss Challenge Mode

for many different application areas and demand requirements.

- Deploying 2 sets of tracks, parallel to each other doubles the design capacity as well as the productive capacity of the given same route. The same can be achieved at 2 levels as well only consuming 1.2 m of aerial RoW.
- Physical Linking of Pods using a mechanical coupler, so that the same can service 4 passengers at the same time while still retaining the same headway and/or frequency between pods.
- Increase the total number of berths at the station to cater to more boarding and alighting.
- Idle parking of empty vehicles at the station itself instead of a distant parking depot for rapid availability of extra vehicles whenever required.

3. AutoBots | Capital Costs[2]



a. Vehicle Units

Small Minimalistic Vehicles without an IC Engine - the cheapest such vehicle under mass production by TATA Group is sold for ~INR 2,00,000. The gross dimension of AutoBots shall be 50% laterally (2-seater front + back - 2000 mm x 1000 mm x 1500 mm L B H) Small battery backup for an emergency, onboard HVAC & infotainment requirement.
DC current is picked up from the rail when idle or charging.

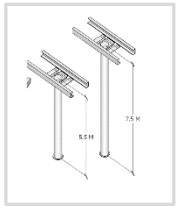
INR 600,000 Each ~ INR 24,000,000 / KM
- 40 vehicles spaced at 25m



b. Guideway Construction

Lightweight & Minimalistic parallel placed Cold Rolled C-Purlin members - gross cross-sectional dimension 150 mm x 450 mm B H) with a plate thickness of 10 mm placed 1.2 m apart. Cross bracing with 10 mm steel plates at regular intervals.

INR 20,000 per M ~ INR 20,000,000 / KM



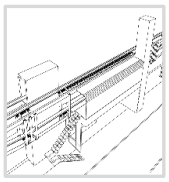
c. Vertical Supports

Slender Minimalistic parallel placed Cold Rolled Tapered Steel Poles - gross cross-sectional diameter of 400 mm) with a plate thickness of 8 mm with Concrete piers embedded into the ground. (Compare with telecom poles truncated to required heights)

No Land Acquisition Costs - only easement rights from city authorities are required.

INR 30,000 Each ~ INR 3,000,000 / KM
- 80 poles spaced at 12.5 m

[2] Broad assumptions as per 2022 Prices in India for a Typical 10 Km System



d. Typical Station Block

Minimalistic access points built as narrow width (1.8m) elevated steel structure concourse and weatherproof enclosure. Each station can be built with a different number of access boarding and alighting bays, normally 4 bays per Station / Direction. A hanging support track for 20 pods as idle parking.

INR 1,500,000 / Bay ~ INR 6,000,000 / KM / Direction
`- 8 bays per Station every 1 Km,
- 4 parking slots per Station Block
- 36 idle Hanging parking slots per Block

e. Pod Idling, Service Depot & OCC

Multi-Level Automated Pod Delivery system besides a Station Block inventory along with a Service Center

INR 30000 / Sqm ~120,000,000 LS / 10 Km Bi-directional
~ INR 6,000,000 / KM
(~4000Sqm Over and above scheduled Pods at Stations at 40 Nos per station)



f. Power, Chassis Automation, Control System & Power Train

Motors with Central Control Systems, Communication lines, Location Sensors, High-Speed Transducers, Cabling for power, and Grid connected Solar Plant for Increasing Energy Efficiency

INR 400,000 / Veh Chassis ~ INR 16,000,000 / KM
- 40 vehicles spaced at 25m

INR 10,000 / m Track Elements ~ INR 10,000,000 / KM
INR 4,000 / m Power Rail ~ INR 4,000,000 / KM

g. License Fees, Operations MIS & AFC

Smart RFID Automatic Fare Collection for a controlled user group. Automated systems shall require few people at stations or for backend operations. Backend MIS is required for reconciliation, personnel, and facility management.
~ INR 100,000,000 LS (10 Km Bidirectional)
- INR 5,000,000 / KM / Direction

Cost basis considering economies of scale &
Excluding Domestic & Import Taxes & Duties
Capital Costs per Installation Km (over say 10 KM Uni-Directional system)
~ INR 94,000,000 / KM

~ INR 184,000,000 / Km Bi Directional
~ INR 18.4 Cr / Km Bi Directional

Table 1: AutoBots Cost Description & CAPEX / Km

4. Linear Alignment Vs Grid Network

AutoBots deployments can be linear or gridded. When deployed along a linear alignment, the system can be compared to a line haul and can be compared to a line system.

When deployed as a grid, the system needs to be compared with any alternate system as a complete grid. (Several lines of intersecting Metro lines)

Requirements for an identified transportation need in an urban or suburban context may be from point-to-point passing through a series of access locations along a linear arrangement of tracks or point to multi-point, across geographical space, all linked using a grid arrangement.

Point-to-point line arrangements will be useful in the early phases of the PRT technology – connecting 2 airports, railway or bus terminals to a city center or city center to a place of tourist interest.

With the maturity of these early applications, the technology will be utilized to cover larger areas in a grid format. Such a format will likely cover large habitat zones or the entire city. This provides the application a unique opportunity to utilize the large system spread in the night-time for ~8 Hrs to provide for last-mile delivery of goods packages from a central warehouse, with a single person at the destination to deliver the same at the purchaser's doorstep. (Analogy of E-Commerce deliveries)

The following analysis looks at both scenarios in this techno-economic feasibility study

Format 1: **System with only passenger movement for ~16 Hrs daily**

Format 2: **System with passenger movements in the daytime for 16 hrs and goods movement for ~8 Hrs every night.**

For either scenario a 20 Km formation is considered to be an ideal 'Business Unit' (BU) that can be scaled to larger deployments (Linear or Grid formats) The following has been assumed further:

- 1 Operations Control Station (OCC) and 1 Maintenance Depot Unit (MDU) per BU.
- Land required for the OCC & the MDU to be granted by the Sponsoring Public Authority (SPA)
- Easement right within the road ROW to install the supporting infrastructure facilitated and granted by the SPA.
- Electrical Power connection to the electric grid is to be granted by the SPA.
- Power Purchase Agreement to be facilitated by the SPA prioritizing Renewable Energy (RE) power producers.
- A Design Finance Build Operate Transfer (DFBOT) format agreement is to be facilitated by the SPA for 30 years.

5. AutoBots Technology System Features

Pod Capacity	2 Pax Groups (Pod Electronically linked for groups >2 Pax) Max 200 Kg payloads for palettized goods
Pod Dimensions	Internal 1.8 m x 0.9 m External 2.4 m x 1.0 m
Pod Speed	Min 45Km/Hr

	Max 100 Km/Hr
Pod Frequency	2s
Pod Headway	25m
Pod Boarding Alighting	120/pod / Hr | 30s per Group (Door Opening (5s), Alighting + Boarding (20s), Door Close (5s) time)
Braking Distance	~22.5m
Max. Line Capacity	3600 Persons Trips/Hr/Direction (Phpdt)
	360 Tonnes Trips/Hr/ Direction

6. AutoBots System Assumptions

Tracks	1 Bi-Directional line	
	2.5 m Aerial RoW	(1.2 m wide per Line)
Support Pillars	80 Units per 100 m	(12.5 m interspacing)
Stations	21 Units	
Station Footprint	3m x 5m per Bay	
	4 Bays per Station	Bay layout in 'File' formation

7. Assumptions for Computations of Commercial & Economic Feasibility

Salient aspects and key metrics regarding the system have been assumed as follows:

Length of Bi-Directional Route	20	km
Length of AutoBots Tracks	40	km
Operational Travel Speed	45	km/hr
Distance Headway	25	m
Time Headway	2	sec
Pods/km/direction	40	Nos.
Cost of One PRT vehicle	1000000	INR
No of Stations	21	Nos.
No of Stations 4 bays	42	Nos.
Cost of 4 Station Bay	6000000	INR
Vertical Supports @ 12.5m	1600	Nos.
Seat Capacity utilization	75%	
Tonne Km Capacity utilization	100%	
Vehicle Load Factor	80%	
Vehicle Lifespan (years)	10	years
Idle Pod Parking	760	Nos.
Parking Depot @ 4.5 Sqm/ Pod	3420	Sqm
Service Depot @ 20% of Depot	684	Sqm
Project Period (years) as DFBOT	30	years

- 2-year period for Infrastructure Development followed by 28 years of operations.

- Alignment and electric infrastructure are constructed at the beginning of a typical concession period itself along with the maintenance depot and Operations Control Station.
- The peak ridership determines the total system capacity. Under a standard scenario, the projected peak is assumed in the 30th year.
- The maximum number of pods that can fit in the system in the 30th year (in a fully mature system) determines the system length and vice-versa.
- Pods are added to the fleet incrementally every 10th year of the operational period to max out in the 30th year.
- Pods are procured using funds raised as debt serviced for a subsequent 5-year period.
- 25% of all the electrical equipment is replaced after the 15th year of operations from available cash reserves.
- 16 Hrs of Passenger transport per day
- 8 Hrs for freight goods transportation at night in a fully gridded city-wide coverage

8. AutoBots Technology System CAPEX | Only Passenger

Bare Technology System Costs for only passenger transport vehicles is INR ~19.9 Crores / Km.

Cost of Technology	Units	Number	Rate	Total Cost (INR Cr)	Taxes
Civil & Structure					
Support Pillars	Nos	1600	30000	4.80	0.58
Guideway Cost	Km	40	20000000	80.00	9.60
Stations Bay Development Cost + MEP	Nos	42	6000000	25.20	3.02
OCC Development Cost + MEP	Nos	1	30000000	3.00	0.44
Traction Power Cost (Third Rail)	Km	40	4000000	16.00	2.32
Track Components	Km	40	10000000	40.00	5.80
Depot					
Pod Idling Depot + MEP	Sqm	4104	30000	12.31	1.48
Control System					
Operation Management Software	Unit	1	1E+08	10.00	1.20
Pod Cost					
Passenger Vehicle Unit Cost	Nos	1600	1000000	160.00	23.20
				351.31	47.63
				398.9	INR Cr
		INR Cr / Km		**9.97**	

Table 2: Technology System CAPEX | Only Passenger Format

9. AutoBots Technology System OPEX | Only Passenger

a. Service Personnel Recurring Expense

Recurring cost on Service Personnel at 30 Nos per station and 640 Nos per BU and an additional ~19 Nos at the Depot and OCC as follows, amounting to INR ~1.5 Cr/Km annually

Recurring Cost at All Stations | System Wide	Units	Number	Monthly Rate	Annual Cost INR Crores
Security + Standby	Nos	120	35000	5.04
Supervisors + Standby	Nos	180	35000	7.56
Booth Manager + Standby	Nos	180	45000	9.72
Service Engineer	Nos	20	60000	1.44
Administration Misc.	Unit	120	20000	2.88
Services - Electricity & Airconditioning	Unit	20	40000	0.96
Recurring Cost Central Depot | Operations Control Centre	Units	Number	Monthly Rate	Annual Cost INR Crores
Security	Nos	3	35000	0.126
Supervisors	Nos	3	35000	0.126
Booth Manager	Nos	3	45000	0.162
Service Engineer	Nos	1	60000	0.072
Accountant	Nos	2	40000	0.096
Administration Misc.	Nos	3	60000	0.216
Services - Electricity & Airconditioning	Nos	2	40000	0.096
General Manager	Nos	2	240000	0.576

Table 3: Personnel Requirement and Cost Details

b. Energy Requirements

S. No	Details	Unit.	Total Daily Requirement (Million)	Total Annual Requirement (Million)
1	Station Load for Station Berths at Station	KW	0.007	2.6
2	Total Power load Requirement for Depot	KW	0.002	0.8
3	Total power load Requirement for Station Lifts + Escalators	KW	0.013	4.9
	Pod Car Consumption with 10 % of cars reserve for maintenance (16 Hrs)			
4	Pod Cars Year Y2 to Y12	KW	0.166	60.5
5	Pod Cars Year Y2 to Y22	KW	0.332	121.1
6	Pod Cars Year Y22 to Y30	KW	0.498	181.6
1	Station Load Calculation for 4 berth station	Unit	Total Requirement	Total Daily Requirement
	Total 4 berth Units in all stations	Nos	42	
	Station Load for 4 Berth Station Daily	sq. m.	36	
a	Internal lighting Load	KW	0.2	
b	External Lighting Load	KW	0.2	
c	AFC Gate Load	KW	2	
d	Track Lighting	KW	2	
e	Cleaning Machine Load	KW	2	
f	Air-conditioning electrical load	KW	2	
g	Miscellaneous	KW	5	
h	Total Electrical Load	KW	13.4	
i	Electrical Load after overall Diversity @ 80%	KW	10.72	172

2	Station Load Calculation for 21 stations	Unit	Total Requirement	Total Daily Requirement
	No of Stations	Nos	21	
a	Elevator Electrical Load (2 elevators 10 KW each)	KW	20	
b	Escalator Electrical Load (2 escalators 15 KW each)	KW	30	
h	Total Electrical Load	KW	50	
c	Electrical Load after overall Diversity @ 80%	KW	40	640
3	Total Power Requirement for Depot	Unit	Total Daily Requirement	Total Daily Requirement
	Total Area of Depot @ 12000 Sqm	sq. m.	12000	
a	Internal Lighting Load	KW	20	
b	External Lighting Load	KW	10	
c	Control Room load	KW	30	
d	Service Station Load (12 stands with 10 kw each)	KW	120	
e	Total Electrical Load after Diversity @ 80%	KW	144	2304
f	DG Set Requirement Load in KVA	KVA	250	
g	At 90% Loading Selection of DG Set	KVA	275	

Table 4: Energy Requirement Details

c. Energy Costs | Passenger

Passenger Vehicle O& M Expense (Annual)	Units	Number	Rate	Annual Cost INR Crores
Pod Cars Year Y2 to Y12	KW	60549120	5.00	30.27
Pod Cars Year Y2 to Y22	KW	121098240	5.00	60.55
Pod Cars Year Y22 to Y30	KW	181647360	5.00	90.82
Cost of Maintenance @5% Cost Pod Fleet +5% YOY	Rs	1600000000	0.05	8.00
Infrastructure O&M (Annual) 16 Hrs				
Station Load for Station Berths at Station	Mil KW	2.63	5.00	1.31
Total Power load Requirement for Depot	Mil KW	0.84	5.00	0.42
Total power load Requirement for Station Lifts + Escalators	Mil KW	4.91	5.00	2.45

Table 5: Summary Costs of Energy Requirements

d. Technology License Fees | Passenger

License Fees (Annual)				
Franchisee Fees for Route + 5% YOY	Km	40	1800000	7.20
Franchisee Fees for Pod Fleet @2% + 5% YOY	Veh	1600	72000	11.52
Application Software License Fee @10% + 5% YOY	%	10%	-	1.00

Table 6: Technology License Fees

10. Revenue Streams

AutoBots deployments can be linear or gridded. Revenue streams in both formats can be from the following sources.

Revenue	Units
From Passenger Trips	Passenger trips/day for 16 Hrs
From Advertisements	Per station per day
In-Vehicle Entertainment Advertisement	Per 10 sec for 16 hrs
From Carbon Credits	tCO2e/day

This analysis discounts the revenue streams from advertisements, in-vehicle infotainments, and or carbon credits.

Fare for each trip of an ATL of ~ 5 Km (location dependent) can range from INR 20 to 50 per trip for AutoBots. This translates to INR 4 to 10 per passenger Km. This is for on-demand Air-conditioned travel.

For the sake of comparison, currently in Indian Cities the following fares Apply for such a trip

Bare Cost of Travel[3]	Per Trip	Subsidy	INR / Km
Metro - ~6 Stations	23	47.9	15.7
E- Rickshaw ~ 1 Km	10		10
Uber Go ~ 5 Km	174.5		34.9
Uber Auto ~ 5 Km	90.5		18.1
Uber Sedan ~ 5 Km	187		37.4

The fare applicable for any such public deployment is generally evolved by the location context, purchasing parity with respect to the socio-economic strata of the riders the system is required to cater to, in discussion with the stakeholders.

A comprehensive Mode choice and mode shift analysis is generally the basis for an appropriate fare policy for the specific location.

11. AutoBots Technology System CAPEX | Passenger & Goods

Bare Technology System Costs for additional goods transport vehicles is INR ~ 20 Crores / Km

Cost of Technology	Units	Number	Rate	Total Cost (INR Cr)	Taxes
Civil & Structure					
Support Pillars	Nos	1600	30000	4.80	0.58
Guideway Cost	Km	40	20000000	80.00	9.60
Stations Bay Development Cost + MEP	Nos	42	6000000	25.20	3.02
OCC Development Cost + MEP	Nos	1	30000000	3.00	0.44

[3] DMRC Website & Uber App

Traction Power Cost (Third Rail)	Km	40	4000000	16.00	2.32
Track Components	Km	40	10000000	40.00	5.80
Depot					
Pod Idling Depot + MEP	Sqm	4104	30000	12.31	1.48
Control System					
Operation Management Software	Unit	1	100000000	10.00	1.20
Pod Cost					
Passenger Vehicle Unit Cost	Nos	1600	1000000	160.00	23.20
Goods Vehicle Unit Cost	Nos	1600	500000	80.00	11.60
Total cost of all Technology Items				431	59
				24.5 INR Cr/Km	

Table 7: Technology System CAPEX | Passenger & Goods Format

12. AutoBots Technology System OPEX | Passenger & Goods

a. Service Personnel Recurring Expense | Passenger & Goods

Recurring cost on Service Personnel at 46 Nos per station and 960 Nos per BU and an additional ~38 Nos at the Depot and OCC as follows, amounting to INR ~3 Cr/Km annually

Recurring Cost at All Stations | System Wide	Units	Number	Monthly Rate	Annual Cost INR Crores
Security + Standby	Nos	180	35000	7.56
Supervisors + Standby	Nos	270	35000	11.34
Booth Manager + Standby	Nos	270	45000	14.58
Service Engineer	Nos	30	60000	2.16
Administration Misc	Unit	180	20000	4.32
Services - Electricity & Airconditioning	Unit	30	40000	1.44
Recurring Cost Central Depot | Office/Month	Units	Number	Rate	Annual Cost INR Crores
Security	Nos	6	35000	0.252
Supervisors	Nos	6	35000	0.252
Booth Manager	Nos	6	45000	0.324
Service Engineer	Nos	2	60000	0.144
Accountant	Nos	4	40000	0.192
Administration Misc	Nos	6	60000	0.432
Services - Electricity & Airconditioning	Nos	4	40000	0.192
General Manager	Nos	4	240000	1.152

Table 8: Personnel Requirement and Cost Details

b. Energy Requirement | Passenger & Goods

S. No	Details	Unit.	Total Daily Requirement (Million)	Total Annual Requirement (Million)

1	Station Load for Station Berths at Station	KW	0.011	3.9
2	Total Power load Requirement for Depot	KW	0.003	1.3
3	Total power load Requirement for Station Lifts + Escalators	KW	0.020	7.4
	Pod Car Consumption with 10 % of cars reserve for maintenance (16 Hrs)			
4	Pod Cars Year Y2 to Y12	KW	0.166	60.5
5	Pod Cars Year Y2 to Y22	KW	0.332	121.1
6	Pod Cars Year Y22 to Y30	KW	0.498	181.6
	Goods Car Consumption with 10 % of cars reserve for maintenance (8 Hrs)			
7	Goods Car Year Y2 to Y12	KW	0.083	30.3
8	Goods Car Year Y2 to Y22	KW	0.166	60.5
9	Goods Car Year Y22 to Y30	KW	0.249	90.8
				557.5
1	Station Load Calculation for 4 berth station	Unit	Total Requirement	Total Daily Requirement
	Total 4 berth Units in all stations	Nos	42	
	Station Load for 4 Berth Station Daily	sq. m.	36	
a	Internal lighting Load	KW	0.2	
b	External Lighting Load	KW	0.2	
c	AFC Gate Load	KW	2	
d	Track Lighting	KW	2	
e	Cleaning Machine Load	KW	2	
f	Air-conditioning electrical load	KW	2	
g	Miscellaneous	KW	5	
h	Total Electrical Load	KW	13.4	
i	Electrical Load after overall Diversity@ 80%	KW	10.72	257
2	Station Load Calculation for 21 stations	Unit	Total Requirement	Total Daily Requirement
	No of Stations	Nos	21	
a	Elevator Electrical Load (2 elevators 10 KW each)	KW	20	
b	Escalator Electrical Load (2 escalators 15 KW each)	KW	30	
h	Total Electrical Load	KW	50	
c	Electrical Load after overall Diversity@ 80%	KW	40	960
3	Total Power Requirement for Depot	Unit	Total Daily Requirement	Total Daily Requirement
	Total Area of Depot @ 12000 Sqm	sq. m.	12000	
a	Internal Lighting Load	KW	20	
b	External Lighting Load	KW	10	
c	Control Room load	KW	30	
d	Service Station Load (12 stands with 10 kw each)	KW	120	
e	Total Electrical Load after Diversity @ 80%	KW	144	3456
f	DG Set Requirement Load in KVA	KVA	250	
g	At 90% Loading Selection of DG Set	KVA	275	
h	Selection of DG	KVA	2 X 275 KVA	

Table 9: Energy Requirement Details

c. Energy Costs | Passenger & Goods

Passenger Vehicle O& M Expense (Annual)	Units	Number	Rate	Annual Cost INR Crores
Pod Cars Year Y2 to Y12	KW	60549120	5.00	30.27
Pod Cars Year Y2 to Y22	KW	121098240	5.00	60.55
Pod Cars Year Y22 to Y30	KW	181647360	5.00	90.82
Cost of Maintenance @5% Cost Pod Fleet +5% YOY	Rs	1600000000	0.05	8.00
Goods Mule O& M Expense (Annual)				
Goods Car Year Y2 to Y12	KW	30274560	5.00	15.14
Goods Car Year Y2 to Y22	KW	60549120	5.00	30.27
Goods Car Year Y22 to Y30	KW	90823680	5.00	45.41
Cost of Maintenance @5% Cost Goods Fleet +5% YOY	Rs	800000000	0.05	4.00
Infrastructure O&M (Annual) 24 Hrs				
Station Load for Station Berths at Station	Mil KW	3.94	5.00	1.97
Total Power load Requirement for Depot	Mil KW	1.26	5.00	0.63
Total power load Requirement for Station Lifts + Escalators	Mil KW	7.36	5.00	3.68

Table 10: Summary Costs of Energy Requirements

d. Technology License Fees | Passenger & Goods

License Fees (Annual)				
Franchisee Fees for Route + 5% YOY	Km	40	1800000	7.20
Franchisee Fees for Pod Fleet @2% + 5% YOY	Veh	1600	72000	11.52
Franchisee Fees for Goods Fleet @2% + 5% YOY	Veh	1600	72000	11.52
Application Software License Fee @10% + 5% YOY	%	10%	-	1.00

Table 11: Technology License Fees

13. Revenue Streams

AutoBots deployments can be linear or gridded. Revenues streams from both formats can be from the following sources.

Revenue	Units
From Passenger Trips	Passenger trips/day for 16 Hrs
From Goods Haulage	Tonne Km/day for 8 Hrs
From Advertisements	Per station per day
In-Vehicle Entertainment Advertisement	Per 10 sec for 16 hrs
From Carbon Credits	tCO2e/day

This analysis discounts the revenue streams from advertisements, in-vehicle infotainments, and or carbon credits.

Fare for each trip of an ATL of ~ 5 Km (location dependent) can range from INR 20 to 50 per trip for AutoBots. This translates to INR 4 to 10 per passenger Km. This is for on-demand Air-conditioned travel.

For the sake of comparison, currently in Indian Cities the following fares Apply for such a trip

Bare Cost of Travel[4]	Per Trip	Subsidy	INR / Km
Metro - ~6 Stations	23	47.9	15.7
E- Rickshaw ~ 1 Km	10		10
Uber Go ~ 5 Km	174.5		34.9
Uber Auto ~ 5 Km	90.5		18.1
Uber Sedan ~ 5 Km	187		37.4

Besides passengers, the fare for transporting one Tonne each Km (again location dependent) can range from INR 50 to 100 per Tonne Km with AutoBots, considering a last 400m delivery by foot @20% of the market cost for transportation (say E-Commerce like packages).

For the sake of comparison, currently, in Indian Cities, the rate for goods transport is ~ INR 100 / Tonne Km

Bare Cost of Transport for 5 Km [5]	Per Trip	INR / Tonne Km
Tata Ace - 780 Kg Capacity	560	143.6
14 Ft Canter Truck - 2400 Kg	1460	121.7
8 Ft Mahindra Pickup Truck - 1500 Kg	770	102.7

[4] DMRC Website & Uber App
[5] Porter Online App

B. Format 1: Passenger-Only Transport-Oriented System

This section describes a typical project deployment and related Cash flows, FIRR, EIRR, and Annualized Returns for a linear / grid format of 20 Km bidirectional alignment with an access station every 1 Km. The system is being deployed to operate for 16 Hrs. daily but intended to carry only passengers over the day.

1. Passenger System Capacities in Year 2, Year 12 & Year 30

Given the peak ridership and full system utilization culminating in the 30th year, one can assume the following 2 scenarios.

- The system is utilized to the designed capacity from day 1 of operations resulting in full revenue accrual from Day 1
- or the ridership increases YOY with a CAGR of (say) 5% resulting in a gradual increase in revenues culminating to a maximum in the 30th year.

It is obvious that the second scenario will yield lesser revenues over the entire period of operations, despite the full system infrastructure put up in place from Day 1 of operations.

The forthcoming financial and economic analysis is based on this poorer scenario.

	Year 2	
PRT Units are replaced 10 yearly	533	Nos.
Capacity of Pods (persons)	2	Nos.
Average Trip Length (weighted average)	4.50	Km
Operating Hours/day (hrs)	16	hrs
No. of Veh trips/day	68266	trips
Total vehicle km/day	307200	Vkm
Seat Km Per day	614400	Skm
Seat Capacity Utilisation	460800	Pkm
Number of Pax Trips	102400	Trips
No of Vehicle Trips with Full Reservation @10%	10240	Veh Trips
No Of Vehicle Trips with Shared Ride	61440	Veh Trips
Total Veh Trips	71680	Veh Trips

	Year 12	
PRT Units replaced 10 yearly	1067	Nos.
Capacity of Pods (persons)	2	Nos.
Average Trip Length (weighted average)	4.50	Km
Operating Hours/day (hrs)	16	hrs
No. of Veh trips/day	136533	trips
Total vehicle km/day	614400	Vehkm
Seat Km Per day	1228800	Seatkm
Seat Capacity Utilisation	921600	Paxkm
Number of Pax Trips	204800	Trips
No of Vehicle Trips with Full Reservation @10%	20480	Veh Trips

No Of Vehicle Trips with Shared Ride	122880	Veh Trips
Total Veh Trips	143360	Veh Trips

	Year 22	
PRT Units replaced 10 yearly	1600	Nos.
Capacity of Pods (persons)	2	Nos.
Average Trip Length (weighted average)	4.50	Km
Operating Hours/day (hrs)	16	hrs
No. of Veh trips/day	204800	trips
Total vehicle km/day	921600	Vehkm
Seat Km Per day	1843200	Seatkm
Seat Capacity Utilisation	1382400	Paxkm
Number of Pax Trips	307200	Trips
No of Vehicle Trips with Full Reservation @10%	30720	Veh Trips
No Of Vehicle Trips with Shared Ride	184320	Veh Trips
Total Veh Trips	215040	Veh Trips

Table 12: Deployment of PRT units commensurate to the growing demand.

2. Summary Ridership Capacities on Offer

Summary capacities on offer every 10 years have been computed as follows

Daily Ridership on Pods + CAGR of 5%		Daily	Annual
Year Y2 to Y12 (533 cars)	Trips	102400	37376000
Year Y12 to Y22 (1067 cars)	Trips	204800	74752000
Year Y22 to Y30 (1600 cars)	Trips	307200	112128000

Table 13: Available capacity Every 10 Years with appended Fleet size

3. Project Capital Expenses (CAPEX)

For a typical deployment time of 2 years, the CAPEX distribution would be as follows.

The investment is employed equally over the 2 pre-operative years. The guideway, Track components, and pods consume the maximum investments (17%, 17%, and 23% respectively)

Cost of Project Deployment	Units	Number	Rate	Total Cost (INR Cr)	Taxes
Company Affairs, Legal & System Sizing				0.90	
Planning Feasibility, Design & Detailing				5.00	
Land Related					
Land Cost	Sqm	821	20000	1.64	
Depot for 4 Storey Structure + MEP	Sqm	76	20000	0.15	
R&R + Utility Shifting	Km	20	10000000	20.00	

Civil & Structure					
Support Pillars	Nos	1600	30000	4.80	0.58
Guideway Cost	Km	40	20000000	80.00	9.60
Stations Bay Development Cost + MEP	Nos	42	6000000	25.20	3.02
OCC Development Cost + MEP	Nos	1	30000000	3.00	0.44
Traction Power Cost (Third Rail)	Km	40	4000000	16.00	2.32
Track Components	Km	40	10000000	40.00	5.80
Depot					
Pod Idling Depot + MEP	Sqm	4104	30000	12.31	1.48
Control System					
Operation Management Software	Unit	1	100000000	10.00	1.20
Pod Cost					
Passenger Vehicle Unit Cost	Nos	1600	1000000	160.00	23.20
Total Cost without Land				357	47.63
General Costs @ 5%				17.87	
Contingencies @3%				10.72	
Total cost of all items including General Charges, and Contingency without land & R&R.				385.80	47.63
Total cost of all items				**455.23 INR Cr**	

Table 14: Investment Schedule for full infrastructure and full rolling stock in the 20th Year

Summarily this translates to

System Costs		
Planning & Design	0.30	Cr/Km
Technology System	17.6	Cr/Km
Technology System Cost + Taxes	19.9	Cr/Km
Technology System Cost + General Costs & Contingencies	19.3	Cr/Km
Technology System Cost + Taxes, General Costs & Contingencies	21.7	Cr/Km
Project Costs		
Land Costs + R&R	1.1	Cr/Km
Pre-Operation + System Cost	19.3	Cr/Km
Pre-Operation + System Cost +Taxes	21.3	Cr/Km
Pre-Operation + System Cost +Taxes + GC + Contingencies	21.7	Cr/Km
All Costs	22.76	Cr/Km

One can assume that only a third of the pods will be required for the first 10 years of the operation, completely replaced with twice the number in the 10 years of operation, and again completely replaced in the 20th year of operation.

The cash flow in the following section considers the deployment of only 33% of the rolling stock and ridership at the start of operations, assuming a pessimistic revenue flow consideration.

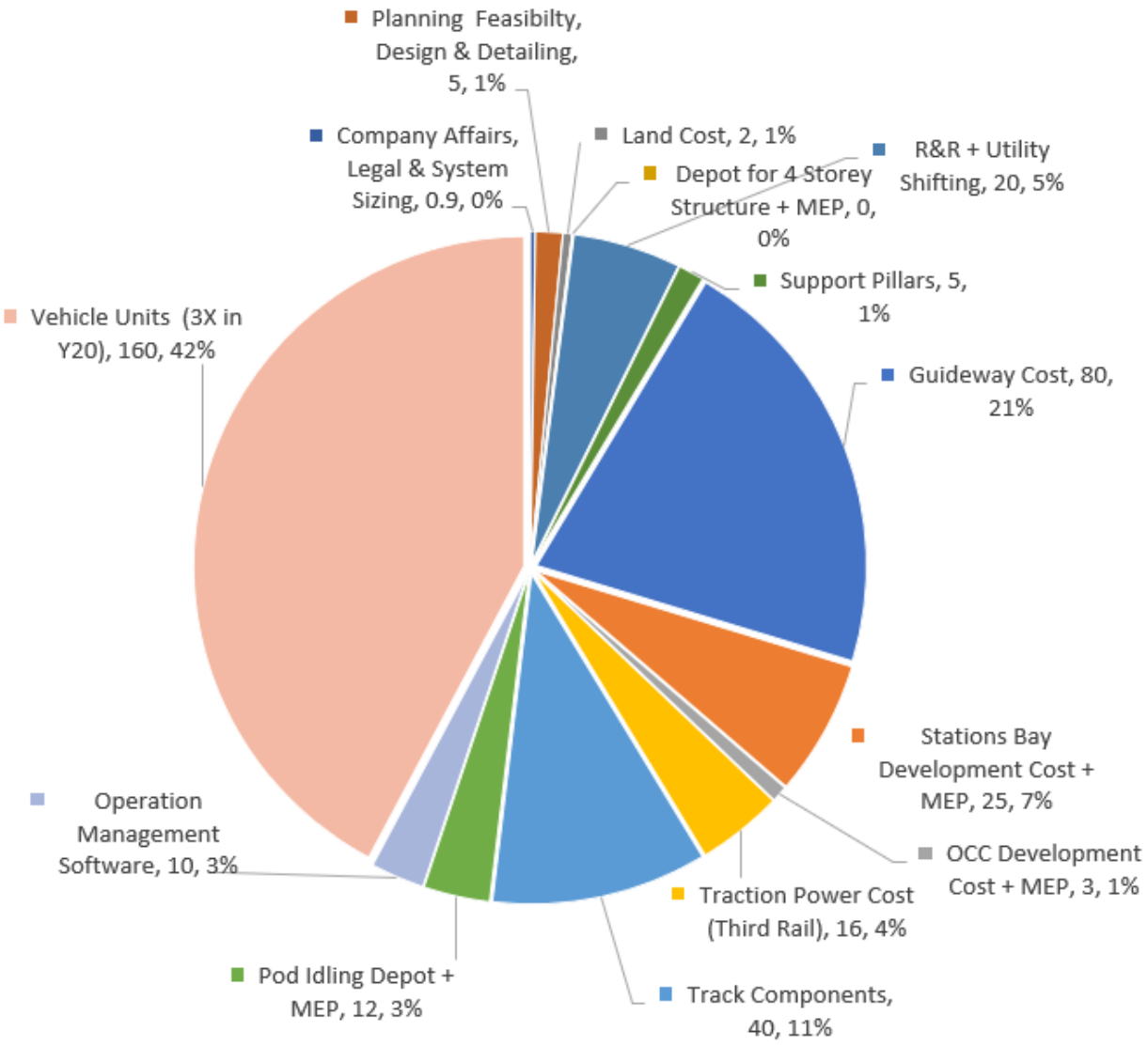


Figure 1: Apportionment of CAPEX in Percentage | Only Passenger Format

4. Project Operational Expenses (OPEX)

a. Service Personnel Recurring Expense

Recurring cost on Service Personnel at 30 Nos per station and 640 Nos per BU and an additional ~19 Nos at the Depot and OCC as follows, amounting to INR ~1.5 Cr/Km annually

Recurring Cost at All Stations | System Wide	Units	Number	Monthly Rate	Annual Cost INR Crores
Security + Standby	Nos	120	35000	5.04
Supervisors + Standby	Nos	180	35000	7.56
Booth Manager + Standby	Nos	180	45000	9.72
Service Engineer	Nos	20	60000	1.44

Administration Misc	Unit	120	20000	2.88
Services - Electricity & Airconditioning	Unit	20	40000	0.96
Recurring Cost Central Depot | Operations Control Centre	Units	Number	Monthly Rate	Annual Cost INR Crores
Security	Nos	3	35000	0.126
Supervisors	Nos	3	35000	0.126
Booth Manager	Nos	3	45000	0.162
Service Engineer	Nos	1	60000	0.072
Accountant	Nos	2	40000	0.096
Administration Misc	Nos	3	60000	0.216
Services - Electricity & Airconditioning	Nos	2	40000	0.096
General Manager	Nos	2	240000	0.576

Table 15: Personnel Requirement and Cost Details

b. Energy Expenses | Passenger

Passenger Vehicle O& M Expense (Annual)	Units	Number	Rate	Annual Cost INR Crores
Pod Cars Year Y2 to Y12	KW	60549120	5.00	30.27
Pod Cars Year Y2 to Y22	KW	121098240	5.00	60.55
Pod Cars Year Y22 to Y30	KW	181647360	5.00	90.82
Cost of Maintenance @5% Cost Pod Fleet +5% YOY	Rs	1600000000	0.05	8.00
Infrastructure O&M (Annual) 16 Hrs				
Station Load for Station Berths at Station	Mil KW	2.63	5.00	1.31
Total Power load Requirement for Depot	Mil KW	0.84	5.00	0.42
Total power load Requirement for Station Lifts + Escalators	Mil KW	4.91	5.00	2.45

Table 16: Summary Costs of Energy Requirements

c. Technology License Fees Expense | Passenger

License Fees (Annual)				
Franchisee Fees for Route + 5% YOY	Km	40	1800000	7.20
Franchisee Fees for Pod Fleet @2% + 5% YOY	Veh	1600	72000	11.52
Application Software License Fee @10% + 5% YOY	%	10%	-	1.00

Table 17: Technology License Fees

5. Revenues

AutoBots deployments can be linear or gridded. Revenue streams for a linear alignment can be from the following sources.

Revenue	Units
From Passenger Trips	Passenger trips/day

From Goods Transport	TonneKm/day
From Advertisements	Per station per day
In-Vehicle Entertainment Advertisement	Per 10 sec for 16 hrs
From Carbon Credits	tCO2e/day

This analysis discounts the revenue streams from goods haulage, advertisements, in-vehicle infotainments, and or carbon credits.

The Fare for each trip of an ATL of 4.5 Km has been assumed to be INR 50.

		Ridership in Million			Weighted Ave Fare / Trip 2021 + 5% YOY	Annual Revenue INR Crores
		Y3-Y12	Y13-Y22	Y23-Y30		
	CAGR	5%	5%	5%	INR 50	
Pre-Operative	Y1					
	Y2					
Operations	Y3	37.38			50	187
	Y4	39.24			53	206
	Y5	41.21			55	227
	Y6	43.27			58	250
	Y7	45.43			61	276
	Y8	47.70			64	304
	Y9	50.09			67	336
	Y10	52.59			70	370
	Y11	55.22			74	408
	Y12	57.98			78	450
	Y13		74.75		81	609
	Y14		78.49		86	671
	Y15		82.41		90	740
	Y16		86.53		94	816
	Y17		90.86		99	899
	Y18		95.40		104	992
	Y19		100.17		109	1093
	Y20		105.18		115	1205
	Y21		110.44		120	1329
	Y22		115.96		126	1465
	Y23			112.13	133	1488
	Y24			117.73	139	1640
	Y25			123.62	146	1808
	Y26			129.80	154	1993
	Y27			136.29	161	2198
	Y28			143.11	169	2423
	Y29			150.26	178	2671
	Y30			157.78	187	2945
						30001

Table 18: Revenues from Fare Box

6. Financial Internal Rate of Return

The Financial Internal Rate of Return (FIRR) without any additional peripheral (PD, Advertisement, Infotainment, etc) income for 30 years life cycle business model including construction period works is tabulated as under.

		Total Revenue from Passenger Trips	Total A Cost of System Deployment	Total C Recurring Cost + 5% YOY	Total Repayment (E)	F Cash flow Operations and CAPEX (A-C)	G Admin, Sales & Mgmt. Cost	H Operating Cash Flow (F - G)	Financial IRR
Pre-Operative	Y1		321			-321	0	-321	
	Y2		315		0	-315	0	-315	
Operations	Y3	187		91	147	96	2	94	
	Y4	206		96	137	110	2	108	
	Y5	227		101	127	127	2	124	-22%
	Y6	250		106	117	145	3	142	-9%
	Y7	276		111	108	165	3	162	0%
	Y8	304		116		188	3	185	6%
	Y9	336		122		213	3	210	10%
	Y10	370		128		242	4	238	14%
	Y11	408		135		273	4	269	16%
	Y12	450	199	154	20	97	4	92	17%
	Y13	609		173	66	436	6	430	19%
	Y14	671		182	61	490	7	483	20%
	Y15	740		191	57	549	7	542	22%
	Y16	816		200	53	616	8	608	23%
	Y17	899		234	48	665	9	656	23%
	Y18	992		221		771	10	761	24%
	Y19	1093		232		862	11	851	24%
	Y20	1205		243		962	12	950	25%
	Y21	1329		255		1074	13	1060	25%
	Y22	1465	486	349	49	630	15	615	25%
	Y23	1488		359	160	1129	15	1114	25%
	Y24	1640		377	150	1263	16	1247	26%
	Y25	1808		396	139	1413	18	1395	26%
	Y26	1993		415	128	1578	20	1558	26%
	Y27	2198		436	118	1762	22	1740	26%
	Y28	2423		458		1965	24	1941	26%
	Y29	2671		481		2191	27	2164	26%
	Y30	2945		505		2440	29	2411	26%
		30001	685	6866	1684	21815	300	21515	26%

Table 19: Cash Flows and Financial Rate of Return | Only Passenger Transport Format

7. Sensitivity

The various sensitivities concerning increase/decrease in capital costs, O&M costs, and fare-box revenues are placed as follows

Case		FIRR	Equity IRR	A ROI
Standard Optimal Model with Incremental Fleet & Ridership (INR 11 / Km for Passenger Trips)		26.3%	24.4%	11.6%
Standard Optimal Model with Full Fleet & Incremental Ridership from Day1 of (INR 11 / Km for Passenger Trips) Operations		17.9%	16%	10%
Standard Optimal Model with Full Fleet & Full Ridership from Day1 of (INR 11 / Km for Passenger Trips) Operations		59%	61%	12%
Standard Optimal Model without Borrowings for Additional Fleet in Y12 & Y22 (INR 11 / Km for Passenger Trips) Operations		25.8%	23.8%	11.6%
Scenario 1	1.5 X Infrastructure Cost +	16.7%	14.4%	8%
	1.5 X Personnel Cost			
Scenario 2	0.5 X Fare Box Revenue (INR 5.5 / Km for Passenger Trips)	12.3%	10.2%	7%
	0.75 X Fare Box Revenue (INR 8.25 / Km for Passenger Trips)	30.5%	19.3%	13%
Scenario 3	1.5 X Infrastructure Cost +	17%	14%	8%
	1.5 X Personnel Cost +			
	0.5 X Fare Box Revenue			

Table 20: Sensitivity Analysis for Up to 50% increase in CAPEX +OPEX & 50% decrease in Fare Box Revenues

8. Financing Options

a. Special Purpose Vehicle

The corridors being standalone and, therefore, forming a separate SPV may be desirable. The State Government can create an SPV for the planning and implementation of PRT systems in the State.

However, like all other SPVs (DMRC-Delhi, LMRCL-Lucknow, Kochi Metro-Kerala, BMRC-Bangalore, CMRL-Chennai, or MMRC-Mumbai) a high Capex Infrastructure project seems to be bogged down by a large equity component besides the State having to absorb all taxes on CAPEX. Although ODA Loan from a multi-lateral or bi-lateral institution is possible, such projects are generally subsidized for both CAPEX & OPEX.

Both FIRR and Equity IRR remain poorer than other alternatives like DFBOT in the longer term, with ODA loan interest & repayment period also lasting the entire project period.

b. DFBOT Model for Implementation

In the model, the private firm will be responsible for financing, designing, building, operating, and maintaining the entire project. This reduces the overall burden on the public exchequer in terms of equity contribution and or bearing applicable taxes.

However, Land may be provided by the Government Agency at no cost to the Concessionaire with the financing model dependent upon the selection of a dedicated agency to implement the project.

Apart from equity contribution from the promoters, it is assumed that the funding for the project shall be achieved through market borrowings. The rate of interest on market borrowings is assumed at 10% p.a. and the repayment of the loan will start immediately after the commercial operations and be repaid in 5 (Five) years.

Accordingly, the funding pattern proposed is placed as under:

Sources of Funds	Amount (Rs/Crore)	% of contribution
Equity by Concessionaire	191	30%
Market Borrowings by Concessionaire	445	70%
Sub-Total (A)	635	100%
Land Cost to be borne Government Agency	2	
Sub-Total (B)	637	
IDC on Loan (to be borne by the Concessionaire)	44	
Total Cost including IDC	682	

Table 21: Funding pattern under DFBOT Model

9. Source of Funds, Interest, and Repayments

A mix of Equity from the Concessionaire & Debt Funds from a lending agency is assumed for the initial CAPEX expenditure to start operations. Replacement and additional vehicles every 10 years of operations are assumed to be procured using debt.

The revenues built up from operational income are assumed to finance all other OPEX during the operational period including the replacement of all electrical equipment in the 15th year.

	Stage 1 Equity	Stage 1 Loan	Stage 2 Equity	Stage 2 Loan	Stage 3 Equity	Stage 3 Loan	Total B
Y1	19065						19065
Y2		44484					44484
Y3							
Y4							
Y5							
Y6							
Y7							
Y8							
Y9							
Y10							
Y11							
Y12				19894			19894
Y13							

Y14							
Y15							
Y16							
Y17							
Y18							
Y19							
Y20							
Y21							
Y22						48608	48608
Y23							
Y24							
Y25							
Y26							
Y27							
Y28							
Y29							
Y30							
							132051

Table 22: Fund Source and Utilization

	IDC on Development Cost	Interest on Term Loan Stage 1	Repayment in 5 Years	Interest on Term Loan Stage 2	Repayment in 5 Years	Interest on Term Loan Stage 3	Repayment in 5 Years	Total Interest (D)	Total Repayment (E)
Y1	19065								19065
Y2		44484							44484
Y3			44484						
Y4			35587						
Y5			26690						
Y6			17794						
Y7			8897						
Y8			0						
Y9									
Y10									
Y11									
Y12					19894				19894
Y13									
Y14									
Y15									
Y16									
Y17									
Y18									
Y19									
Y20									
Y21									
Y22							48608		48608
Y23								48608	
Y24								38887	

Y25								29165	
Y26								19443	
Y27								9722	
Y28								0	
Y29									
Y30									
									132051

Table 23: Interest on Borrowed Capital and Repayments

10. Cash Flow for Equity IRR & Annualized Rate of Return

With a DFBOT financing model and various assumptions, the FIRR, Equity IRR, and annualized returns considering an incrementally growing ridership and revenues for the concessionaire works out to 116%, 160%, and 16% respectively, without considering additional potential revenues from advertisements, property development, carbon credits, and in-vehicle infotainment.

		Total Revenue from Passenger Trips	Total A Cost of	Total C Recurring Cost + 5% YOY	Total Repayment (E)	F Cash flow Operations and	G Admin, Sales &	H Operating Cash Flow	I PBDT (H+A-C)	J Depreciation	K Profit Before Tax (I - J)	L Taxation	M Cash Flow after Capex and Tax (H - L)	N Cash flows for Debt	O Cash Flows after Debt Inflows and	O Cumulative Cash & Reserves	Equity IRR	Annualised Return on Investment
Pre-Operative	Y1		321			-321	0	-321		0	0	0	-321	0	-321			
	Y2		315		44	-315	0	-315		40	-85	0	-359	445	86			
Operations	Y3	187		91	133	96	2	94	49	31	18	5	44	-89	-45	187		
	Y4	206		96	125	110	2	108	73	25	47	14	58	-89	-31	206		
	Y5	227		101	116	127	2	124	98	21	77	23	74	-89	-14	227	-39%	
	Y6	250		106	107	145	3	142	125	17	107	32	92	-89	3	250	-21%	
	Y7	276		111	98	165	3	162	154	14	139	42	112	-89	23	276	-8%	
	Y8	304		116		188	3	185	185	12	173	52	133	0	133	304	2%	
	Y9	336		122		213	3	210	210	10	200	60	150	0	150	336	8%	
	Y10	370		128		242	4	238	238	9	229	69	169	0	169	370	13%	-15%
	Y11	408		135		273	4	269	269	8	261	78	191	0	191	408	16%	-6%
	Y12	450	199	154	20	97	4	92	271	45	226	68	5	199	204	450	16%	-5%
	Y13	609		173	60	436	6	430	410	37	373	112	298	-40	258	609	18%	0%
	Y14	671		182	56	490	7	483	467	30	437	131	336	-40	296	671	20%	3%
	Y15	740		191	52	549	7	542	530	24	506	152	378	-40	339	740	21%	6%
	Y16	816		200	48	616	8	608	600	20	580	174	426	-40	386	816	22%	7%
	Y17	899		234	44	665	9	656	652	16	636	191	461	-40	422	899	23%	8%
	Y18	992		221		771	10	761	761	14	748	224	537	0	537	992	24%	9%
	Y19	1093		232		862	11	851	851	11	839	252	599	0	599	1093	25%	10%
	Y20	1205		243		962	12	950	950	9	941	282	668	0	668	1205	25%	10%
	Y21	1329		255		1074	13	1060	1060	8	1052	316	745	0	745	1329	25%	11%
	Y22	1465	486	349	49	630	15	615	1053	100	953	286	281	486	767	1465	26%	10%
	Y23	1488		359	146	1129	15	1114	1065	80	985	296	770	-97	673	1488	26%	11%
	Y24	1640		377	136	1263	16	1247	1208	64	1144	343	865	-97	768	1640	26%	11%
	Y25	1808		396	126	1413	18	1395	1365	52	1314	394	971	-97	874	1808	26%	11%

	Y26	1993		415	117	1578	20	1558	1539	42	1497	449	1090	-97	992	1993	26%	11%
	Y27	2198		436	107	1762	22	1740	1730	34	1696	509	1221	-97	1124	2198	26%	11%
	Y28	2423		458		1965	24	1941	1941	27	1914	574	1367	0	1367	2423	27%	11%
	Y29	2671		481		2191	27	2164	2164	22	2142	643	1521	0	1521	2671	27%	11%
	Y30	2945		505		2440	29	2411	2411	18	2393	718	1693	0	1693	2945	27%	11%
																	27%	11%

Table 24: Equity IRR & Annualized Rate of Returns on Investment | Only Passenger Transport Format

C. Format 2: Day Passenger + Night Time Freight Goods

Since the infrastructure would be in place right from Day 1 of Operations, the same can be utilized for the transport of freight goods at night.

In the longer term, one envisages all e-Commerce deliveries to use this infrastructure since access points will be distributed to cover the last 300 m walk distances, especially in the case of a city-wide grid deployment. With large distribution hubs on the periphery of the city, a substantial volume of HCV & LCV traffic can be reduced from city streets.

A secondary comparative projection of cash flows and returns has been computed based on this assumption with the same 20 Km stretch as a typical deployment unit representing the entire city-wide grid.

At a city level, the grid can run into 1250 Km for a city spread of 25 Km x 25 Km with 1250 access points spread across the city grid serving the last 500m walk distance from any access point.

Theoretical grid 25Km x 25Km with a single trip of ~5Km with 1 Pod.

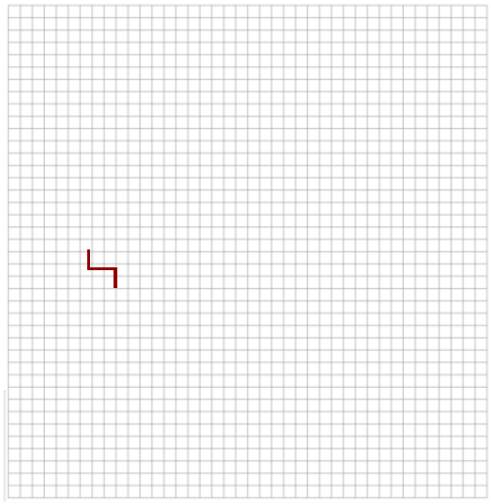


Figure 2: City Wide Grid Format for passengers & goods transport

1. Additional Goods Transport Capacities in Year 2, Year 12 & Year 30

Given the peak ridership and full system utilization culminating in the 30th year, one can assume the following 2 scenarios.

- The system is utilized to the designed capacity from day 1 of operations resulting in full revenue accrual from Day 1
- or the ridership increases YOY with a CAGR of (say) 5% resulting in a gradual increase in revenues culminating to a maximum in the 30th year.

It is obvious that the second scenario will yield lesser revenues over the entire period of operations, despite the full system infrastructure put up in place from Day 1 of operations.

The forthcoming financial and economic analysis is based on this poorer scenario.

	Year 2	
Goods Units replaced 10 yearly	533	Nos.
Capacity of Carrier (Goods)	200	Kg
Average Trip Length (weighted average)	4.50	Km
Operating Hours/day (hrs)	8	hrs
No. of Veh trips / day	34133	trips
Total vehicle km / day (8Hrs)	153600	Vkm
Tonne Km Per day	30720	TKm
Tonne Km Capacity Utilisation	30720	Tkm
Number of Pax Trips	6826	Trips

	Year 12	
Goods Units replaced 10 yearly	1067	Nos.
Capacity of Carrier (Goods)	200	Kg
Average Trip Length (weighted average)	4.50	Km
Operating Hours/day (hrs)	8	hrs
No. of Veh trips / day	68266	trips
Total vehicle km / day (8Hrs)	307200	Vkm
Tonne Km Per day	61440	TKm
Tonne Km Capacity Utilisation	61440	Tkm
Number of Pax Trips	13653	Trips

	Year 22	
Goods Units replaced 10 yearly	1600	Nos.
Capacity of Pods (Goods)	200	Kg
Average Trip Length (weighted average)	4.50	Km
Operating Hours/day (hrs)	8	hrs
No. of Veh trips / day	102400	trips
Total vehicle km / day (8Hrs)	460800	Vkm
Tonne Km Per day	92160	TKm
Tonne Km Capacity Utilisation	92160	Tkm
Number of Pax Trips	20480	Trips

Table 25: Deployment of goods carrier units commensurate to the growing demand.

2. Summary Ridership Capacities on Offer

Summary capacities on offer every 10 years have been computed as follows

Daily Goods Haulage + CAGR of 5%		Daily	Annual
Year Y2 to Y12 (533 cars)	Tonne Km	30720	11212800
Year Y12 to Y 22 (1067 cars)	Tonne Km	61440	22425600
Year Y22 to Y30 (1600 cars)	Tonne Km	92160	33638400

Table 26: Available haulage capacity Every 10 Years with appended Fleet size

3. Project Capital Expenses (CAPEX)

For a typical deployment time of 2 years, the CAPEX distribution would be as follows.

The investment is employed equally over the 2 pre-operative years. The guideway, Track components, and pods consume the maximum investments (17%, 17%, and 23% respectively)

Cost of Project Deployment	Units	Number	Rate	Total Cost (INR Cr)	Taxes
Company Affairs, Legal & System Sizing				0.90	
Planning Feasibility, Design & Detailing				5.00	
Land Related					
Land Cost	Sqm	821	20000	1.64	
Depot for 4 Storey Structure + MEP	Sqm	76	20000	0.15	
R&R + Utility Shifting	Km	20	10000000	20.00	
Civil & Structure					
Support Pillars	Nos	1600	30000	4.80	0.58
Guideway Cost	Km	40	20000000	80.00	9.60
Stations Bay Development Cost + MEP	Nos	42	6000000	25.20	3.02
OCC Development Cost + MEP	Nos	1	30000000	3.00	0.44
Traction Power Cost (Third Rail)	Km	40	4000000	16.00	2.32
Track Components	Km	40	10000000	40.00	5.80
Depot					
Pod Idling Depot + MEP	Sqm	4104	30000	12.31	1.48
Control System					
Operation Management Software	Unit	1	100000000	10.00	1.20
Pod Cost					
Passenger Vehicle Unit Cost	Nos	1600	1000000	160.00	23.20
Goods Vehicle Unit Cost	Nos	1600	500000	80.00	11.60
Total Cost without Land				437	59.23
General Costs @ 5%				21.87	
Contingencies @3%				13.12	
Total cost of all items including General Charges, and Contingency without land & R&R.				472.20	59.23
Total cost of all items				**553.23 INR Cr**	

Table 27: Investment Schedule for full infrastructure and full rolling stock in the 20th Year

Summarily this translates to

System Costs		
Planning & Design	0.30	
Technology System	21.6	Cr/Km
Technology System Cost + Taxes	24.5	Cr/Km
Technology System Cost + General Costs & Contingencies	23.6	Cr/Km
Technology System Cost + Taxes, General Costs & Contingencies	26.6	Cr/Km

Project Costs		
Land Costs + R&R	1.1	Cr/Km
Pre-Operation + System Cost	23.6	Cr/Km
Pre-Operation + System Cost +Taxes	25.9	Cr/Km
Pre-Operation + System Cost +Taxes + GC + Contingencies	26.6	Cr/Km
All Costs	27.66	Cr/Km

One can assume that only a third of the carriers will be required for the first 10 years of the operation, completely replaced with twice the number in the 10 years of operation, and again completely replaced in the 20th year of operation.

The cash flow in the following section considers the deployment of only 33% of the rolling stock and ridership at the start of operations, assuming a pessimistic revenue flow consideration.

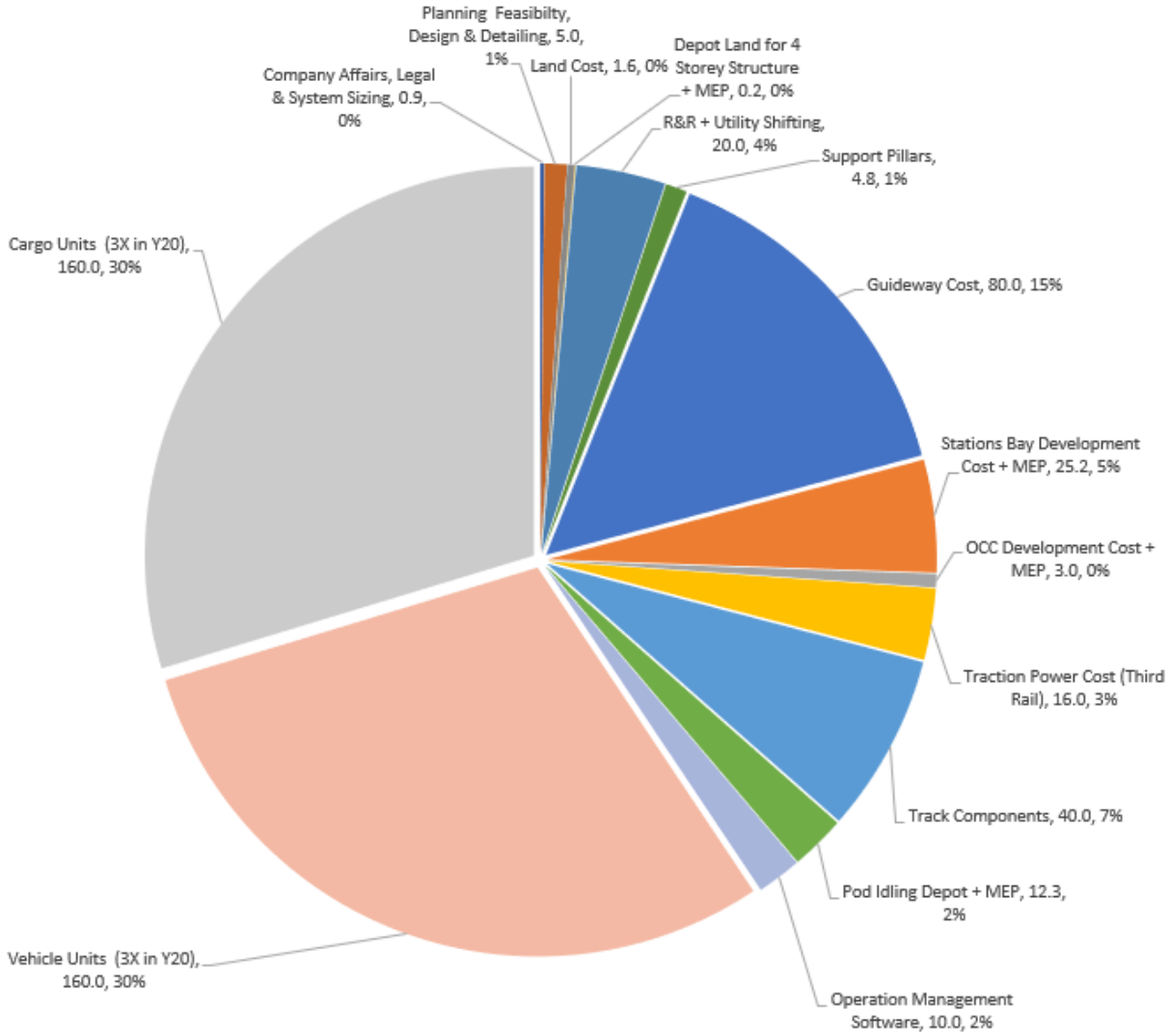


Figure 3: Apportionment of CAPEX in Percentage | Passenger & Goods Format

4. Project Operational Expenses (OPEX)

a. Service Personnel Recurring Expense

Recurring cost on Service Personnel at 46 Nos per station and 960 Nos per BU and an additional ~38 Nos at the Depot and OCC as follows, amounting to INR ~2.22 Cr/Km annually

Recurring Cost at All Stations | System Wide	Units	Number	Monthly Rate	Annual Cost INR Crores
Security + Standby	Nos	180	35000	7.56
Supervisors + Standby	Nos	270	35000	11.34
Booth Manager + Standby	Nos	270	45000	14.58
Service Engineer	Nos	30	60000	2.16
Administration Misc.	Unit	180	20000	4.32
Services - Electricity & Airconditioning	Unit	30	40000	1.44
Recurring Cost Central Depot | Operations Control Centre	Units	Number	Monthly Rate	Annual Cost INR Crores
Security	Nos	6	35000	0.252
Supervisors	Nos	6	35000	0.252
Booth Manager	Nos	6	45000	0.324
Service Engineer	Nos	2	60000	0.144
Accountant	Nos	4	40000	0.192
Administration Misc.	Nos	6	60000	0.432
Services - Electricity & Airconditioning	Nos	4	40000	0.192
General Manager	Nos	4	240000	1.152

Table 28: Personnel Requirement and Cost Details

b. Energy Expenses | Passenger + Goods

Passenger Vehicle O& M Expense	Units	Number	Rate	Annual Cost INR Crores
Pod Cars Year Y2 to Y12	KW	60549120	5.00	30.27
Pod Cars Year Y2 to Y22	KW	121098240	5.00	60.55
Pod Cars Year Y22 to Y30	KW	181647360	5.00	90.82
Cost of Maintenance @5% Cost Pod Fleet +5% YOY	Rs	1600000000	0.05	8.00
Goods Vehicle O& M Expense				
Goods Car Year Y2 to Y12	KW	30274560	5.00	15.14
Goods Car Year Y2 to Y22	KW	60549120	5.00	30.27
Goods Car Year Y22 to Y30	KW	90823680	5.00	45.41
Cost of Maintenance @5% Cost Goods Fleet +5% YOY	Rs	800000000	0.05	4.00
Infrastructure O&M (Annual) 24 Hrs				
Station Load for Station Berths at Station	Mil KW	3.94	5.00	1.97
Total Power load Requirement for Depot	Mil KW	1.26	5.00	0.63
Total power load Requirement for Station Lifts + Escalators	Mil KW	7.36	5.00	3.68

Table 29: Summary Costs of Energy Requirements

c. Technology License Fees Expense | Passenger + Goods

License Fees (Annual)	Units	Number	Rate	Annual Cost INR Crores
Franchisee Fees for Route + 5% YOY	Km	40	1800000	7.20
Franchisee Fees for Pod Fleet @2% + 5% YOY	Veh	1600	72000	11.52
Application Software License Fee @10% + 5% YOY	Veh	1600	72000	11.52

Table 30: Technology License Fees

5. Revenues

AutoBots deployments can be linear or gridded. Revenue streams for a linear alignment can be from the following sources.

Revenue	Units
From Passenger Trips	Passenger trips/day
From Goods Transport	TonneKm/day
From Advertisements	Per station per day
In-Vehicle Entertainment Advertisement	Per 10 sec for 16 hrs
From Carbon Credits	tCO2e/day

This analysis discounts the revenue streams from goods haulage, advertisements, and or carbon credits.

- The Fare for each trip of an ATL of 4.5 Km has been assumed to be INR 50.
- The Cost of Goods Haulage for a Tonne of goods being transported at a distance of 1 Km has been assumed to be INR 50
- The revenues from infotainment is Per 10 sec for 10 hrs with 2.5Hr Advertisement Time working to 900 10 s Spots sold for INR 2000. Such a broadcast will be consumed across the entire fleet to passengers. (Tabulated in the FIRR Cash Flow Table)

	Ridership Million	Y3-Y12	Y13-Y22	Y23-Y30	Weighted Ave Fare / Trip Y2 + 5% YOY	Annual Revenue INR Crores
	CAGR	5%	5%	5%	INR 50	
Pre-Operative	Y1					
	Y2					
Operations	Y3	37.38			50	187
	Y4	39.24			53	206
	Y5	41.21			55	227
	Y6	43.27			58	250
	Y7	45.43			61	276
	Y8	47.70			64	304
	Y9	50.09			67	336
	Y10	52.59			70	370
	Y11	55.22			74	408

	Y12	57.98			78	450
	Y13		74.75		81	609
	Y14		78.49		86	671
	Y15		82.41		90	740
	Y16		86.53		94	816
	Y17		90.86		99	899
	Y18		95.40		104	992
	Y19		100.17		109	1093
	Y20		105.18		115	1205
	Y21		110.44		120	1329
	Y22		115.96		126	1465
	Y23			112.13	133	1488
	Y24			117.73	139	1640
	Y25			123.62	146	1808
	Y26			129.80	154	1993
	Y27			136.29	161	2198
	Y28			143.11	169	2423
	Y29			150.26	178	2671
	Y30			157.78	187	2945
						30001

Table 31: Revenues from Fare Box | Passengers

	Haulage Million Tonnes Km	Y3-Y12	Y13-Y22	Y23-Y30	Weighted Ave Fare / Tonne Km Y2 + 5% YOY	Annual Revenue INR Crores
	CAGR	5%	5%	5%	INR 50	
Pre-Operative	Y1					
	Y2					
Operations	Y3	56.06			50	280
	Y4	58.87			53	309
	Y5	61.81			55	341
	Y6	64.90			58	376
	Y7	68.15			61	414
	Y8	71.55			64	457
	Y9	75.13			67	503
	Y10	78.89			70	555
	Y11	82.83			74	612
	Y12	86.97			78	675
	Y13		112.13		81	913
	Y14		117.73		86	1007
	Y15		123.62		90	1110
	Y16		129.80		94	1224
	Y17		136.29		99	1349
	Y18		143.11		104	1488
	Y19		150.26		109	1640
	Y20		157.78		115	1808
	Y21		165.66		120	1993
	Y22		173.95		126	2198
	Y23			168.19	133	2231

	Y24			176.60	139	2460
	Y25			185.43	146	2712
	Y26			194.70	154	2990
	Y27			204.44	161	3297
	Y28			214.66	169	3635
	Y29			225.39	178	4007
	Y30			236.66	187	4418
						45001

Table 32: Revenues from Fare Box | Goods

6. Financial Internal Rate of Return

The Financial Internal Rate of Return (FIRR) without any additional peripheral (PD, Advertisement, Infotainment, etc.) income for 30 years life cycle business model including construction period works is tabulated as under.

	Revenue Inflows + 5% YOY	From Passenger Trips	From Goods Transport	In-Vehicle Entertainment	Total Revenue	Total A Cost of System	Total B Source of Funds	Total C Recurring Cost + 5% YOY	Total Interest (D2)	Total Repayment (E)	F Cash flow Operations and	G Admin, Sales & Mgmt. Cost	H Operating Cash Flow	Financial IRR
Pre-Operative	Y1					197	116				-197		-197	
	Y2					191	272		27	27	-191		-191	
Operations	Y3	187	280	66	533			117	27	82	415	5	410	
	Y4	206	309	69	584			123	22	76	461	6	455	
	Y5	227	341	72	640			129	16	71	511	6	504	67%
	Y6	250	376	76	702			136	11	65	566	7	559	75%
	Y7	276	414	80	770			143	5	60	627	8	620	79%
	Y8	304	457	84	845			150			695	8	687	82%
	Y9	336	503	88	927			157			770	9	760	83%
	Y10	370	555	92	1017			165			852	10	842	84%
	Y11	408	612	97	1117			173			943	11	932	84%
	Y12	450	675	102	1226	385	385	201	39	39	640	12	628	84%
	Y13	609	913	107	1629			228	39	116	1401	16	1385	84%
	Y14	671	1007	112	1790			239	31	108	1551	18	1533	85%
	Y15	740	1110	118	1968			251	23	100	1717	20	1697	85%
	Y16	816	1224	124	2164			264	15	92	1900	22	1878	85%
	Y17	899	1349	130	2379			301	8	85	2078	24	2054	85%
	Y18	992	1488	137	2616			291			2325	26	2299	85%
	Y19	1093	1640	143	2877			305			2572	29	2543	85%
	Y20	1205	1808	151	3164			320			2844	32	2812	85%
	Y21	1329	1993	158	3481			336			3144	35	3109	85%
	Y22	1465	2198	166	3829	941	941	474	94	94	2413	38	2375	85%
	Y23	1488	2231	174	3893			486	94	282	3407	39	3368	85%
	Y24	1640	2460	183	4283			511	75	264	3772	43	3729	85%
	Y25	1808	2712	192	4712			536	56	245	4176	47	4129	85%

	Y26	1993	2990	202	5185			563	38	226	4622	52	4570	85%
	Y27	2198	3297	212	5706			591	19	207	5115	57	5058	85%
	Y28	2423	3635	222	6280			621			5659	63	5596	85%
	Y29	2671	4007	234	6912			652			6260	69	6191	85%
	Y30	2945	4418	245	7608			684			6924	76	6848	85%
		30001	45001	3837	78840	1715	1715	9149	639	2238		788	67187	85%

Table 33: Cash Flows and Financial Rate of Return | Passengers + Goods

7. Sensitivity

The various sensitivities concerning increase/decrease in capital costs, O&M costs, and fare-box revenues are placed as follows

Case		FIRR	Equity IRR	A ROI
Standard Optimal Model with Incremental Fleet (INR 11 / Km for Passenger Trips & INR 50 / Tonne Km for goods)		84.7%	91.0%	18.6%
Standard Optimal Model with Full Fleet & Incremental Ridership from Day 1 of Operations (INR 11 / Km for Passenger Trips & INR 50 / Tonne Km for goods)		72.16%	78%	17%
Standard Optimal Model with Full Fleet & Full Ridership from Day1 of (INR 11 / Km for Passenger Trips & INR 50 / Tonne Km for goods)		199%	201%	19%
Standard Optimal Model without Borrowings for Additional Fleet in Y12 & Y22 (INR 11 / Km for Passenger Trips & INR 50 / Tonne Km for goods)		89.3%	95.8%	18.6%
Scenario 1	1.5 X Infrastructure Cost +	66.6%	71.8%	16.8%
	1.5 X Personnel Cost			
Scenario 2	0.5 X Fare Box Revenue (INR 5.5 / Km for Passenger Trips & INR 25 / Tonne Km for goods)	50.0%	53.0%	15.2%
	0.75 X Fare Box Revenue (INR 8.25 / Km for Passenger Trips & INR 37 / Tonne Km for Goods)	71.1%	76.6%	17.2%
Scenario 3	1.5 X Infrastructure Cost +	33.1%	33.7%	12.9%
	1.5 X Personnel Cost +			
	0.5 X Fare Box Revenue			

Table 34: Sensitivity Analysis for Upto 50% increase in CAPEX +OPEX & 50% decrease in Fare Box Revenues

8. Financing Options

a. Special Purpose Vehicle

The corridors being standalone and, therefore, forming a separate SPV may be desirable. The State Government can create an SPV for the planning and implementation of PRT systems in the State.

However, like all other SPVs (DMRC-Delhi, LMRCL-Lucknow, Kochi Metro-Kerala, BMRC-Bangalore, CMRL-Chennai, or MMRC-Mumbai) a high Capex Infrastructure project seems to be bogged down by a large equity component besides the State having to absorb all taxes on CAPEX. Although ODA Loan from a multi-lateral or bi-lateral institution is possible, such projects are generally subsidized for both CAPEX & OPEX.

Both FIRR and Equity IRR remain poorer than other alternatives like DFBOT in the longer term, with ODA loan interest & repayment period also lasting the entire project period.

b. DFBOT Model for Implementation

In the model, the private firm will be responsible for financing, designing, building, operating, and maintaining the entire project. This reduces the overall burden on the public exchequer in terms of equity contribution and or bearing applicable taxes.

However, Land may be provided by the Government Agency at no cost to the Concessionaire with the financing model dependent upon the selection of a dedicated agency to implement the project.

Apart from equity contribution from the promoters, it is assumed that the funding for the project shall be achieved through market borrowings. The rate of interest on market borrowings is assumed at 10% p.a. and the repayment of the loan will start immediately after the commercial operations and be repaid in 5 (Five) years.

Accordingly, the funding pattern proposed is placed as under:

Sources of Funds	Amount (Rs/Crore)	% of contribution
Equity by Concessionaire	116	30%
Market Borrowings by Concessionaire	272	70%
Sub-Total (A)	388	100%
Land Cost to be borne Government Agency	2	
Sub-Total (B)	390	
IDC on Loan (to be borne by the Concessionaire)	27	
Total Cost including IDC	417	

Table 35: Funding pattern under DFBOT Model

9. Source of Funds, Interest, and Repayments

A mix of Equity from the Concessionaire & Debt Funds from a lending agency is assumed for the initial CAPEX expenditure to start operations. Replacement and additional vehicles every 10 years of operations are assumed to be procured using debt.

The revenues built up from operational income are assumed to finance all other OPEX during the operational period including the replacement of all electrical equipment in the 15th year.

	Stage 1 Equity	Stage 1 Loan	Balance of Loan	Stage 2 Loan	Balance of Loan	Stage 3 Loan	Balance of Loan	**Total B Source of Funds**
Y1	116.5							116
Y2		271.8						272
Y3			271.8					
Y4			217.4					
Y5			163.1					
Y6			108.7					
Y7			54.4					
Y8			0.0					
Y9								
Y10								
Y11								
Y12				385.3				385
Y13					385.3			
Y14					308.2			
Y15					231.2			
Y16					154.1			
Y17					77.1			
Y18					0.0			
Y19								
Y20								
Y21								
Y22						941.4		941
Y23							941.4	
Y24							753.1	
Y25							564.8	
Y26							376.6	
Y27							188.3	
Y28							0.0	
Y29								
Y30								
								1715

Table 36: Fund Source and Utilization

All debt is assumed to be serviced at an interest of 5% and the repayment periods are assumed to be over the next 5 years from the year of disbursement.

	Interest on Term Loan Stage 1	Repayment in 5 Years	Interest on Term Loan Stage 2	Repayment in 5 Years	Interest on Term Loan Stage 3	Repayment in 5 Years	Total Interest (D2)	Total Repayment (E)
Y1								
Y2	27							27
Y3		27	54					27
Y4		22	54					22

Y5		16	54					16
Y6		11	54					11
Y7			54					5
Y8								
Y9								
Y10								
Y11								
Y12				39				39
Y13				39	77			39
Y14				31	77			31
Y15				23	77			23
Y16				15	77			15
Y17					77			8
Y18								
Y19								
Y20								
Y21								
Y22						94		94
Y23						94	188	94
Y24						75	188	75
Y25						56	188	56
Y26						38	188	38
Y27							188	19
Y28								
Y29								
Y30								
								639

Table 37: Interest on Borrowed Capital and Repayments

10. Cash Flow for Equity IRR & Annualized Rate of Return

With a DFBOT financing model and various assumptions, the FIRR, Equity IRR, and annualized returns considering an incrementally growing ridership and revenues for the concessionaire works out to 250%, 251%, and 19% respectively, without considering additional potential revenues from advertisements, property development, and in-vehicle infotainment.

		Total Revenue from Pass + Goods Trips + Infotainment	Total A Cost of System Deployment	Total C Recurring Cost + 5% YOY	Total Repayment (E)	F Cash flow Operations and CAPEX (A-C)	G Admin, Sales & Mgmt.	H Operating Cash Flow (F - G)	I PBDT(H+A-C)	J Depreciation	K Profit Before Tax (I - J)	L Taxation	M Cash Flow after Interest, Capex, and Tax (H - L)	N Cash flows for Debt	O Cash Flows after Debt Inflows and Outflows	Equity IRR	Annualised Return on Investment
Pre-Operative	Y1		197			-197		-197	0	0	0		-197	0	-197		
	Y2		191		27	-191		-191	-27	52	-79		-191	272	81		

Operations	Y3	533		117	82	415	5	410	383	41	342	103	280	-54	226	29%	
	Y4	584		123	76	461	6	455	433	33	401	120	313	-54	259	62%	
	Y5	640		129	71	511	6	504	488	26	462	139	350	-54	295	76%	
	Y6	702		136	65	566	7	559	548	22	527	158	390	-54	336	83%	
	Y7	770		143	60	627	8	620	614	18	596	179	435	-54	381	86%	24%
	Y8	845		150		695	8	687	687	15	672	201	485	0	485	88%	25%
	Y9	927		157		770	9	760	760	13	748	224	536	0	536	90%	26%
	Y10	1017		165		852	10	842	842	11	831	249	593	0	593	90%	25%
	Y11	1117		173		943	11	932	932	9	923	277	655	0	655	90%	25%
	Y12	1226	385	201	39	640	12	628	975	48	927	278	311	385	697	91%	25%
	Y13	1629		228	116	1401	16	1385	1347	37	1310	393	954	-77	877	91%	24%
	Y14	1790		239	108	1551	18	1533	1503	30	1473	442	1061	-77	984	91%	24%
	Y15	1968		251	100	1717	20	1697	1674	24	1650	495	1179	-77	1102	91%	23%
	Y16	2164		264	92	1900	22	1878	1863	20	1843	553	1310	-77	1233	91%	23%
	Y17	2379		301	85	2078	24	2054	2047	16	2030	609	1437	-77	1360	91%	22%
	Y18	2616		291		2325	26	2299	2299	14	2286	686	1613	0	1613	91%	22%
	Y19	2877		305		2572	29	2543	2543	11	2532	760	1783	0	1783	91%	22%
	Y20	3164		320		2844	32	2812	2812	9	2803	841	1971	0	1971	91%	21%
	Y21	3481		336		3144	35	3109	3109	8	3102	930	2179	0	2179	91%	21%
	Y22	3829	941	474	94	2413	38	2375	3222	100	3123	937	1344	941	2285	91%	21%
	Y23	3893		486	282	3407	39	3368	3274	80	3194	958	2316	-188	2127	91%	20%
	Y24	4283		511	264	3772	43	3729	3654	64	3590	1077	2577	-188	2389	91%	20%
	Y25	4712		536	245	4176	47	4129	4073	52	4021	1206	2866	-188	2678	91%	19%
	Y26	5185		563	226	4622	52	4570	4533	42	4491	1347	3185	-188	2997	91%	19%
	Y27	5706		591	207	5115	57	5058	5039	34	5006	1502	3538	-188	3349	91%	19%
	Y28	6280		621		5659	63	5596	5596	27	5569	1671	3926	0	3926	91%	18%
	Y29	6912		652		6260	69	6191	6191	22	6169	1851	4340	0	4340	91%	18%
	Y30	7608		684		6924	76	6848	6848	18	6830	2049	4799	0	4799	91%	18%
		45001														91%	18%

Table 38: Equity IRR & Annualized Rate of Returns on Investment

D. Summary of Typical AutoBots System

1. Financial Returns

As can be seen, substantially high Financial & Equity IRR is expected from a typical AutoBots system because of the following key reasons:

- Lower CAPEX reduces the overall interest servicing of borrowed capital, therefore early repayments.
- Incremental addition of vehicles/carriers reduces the CAPEX burden yet can service the incremental demand yielding a substantially high FIRR, Equity IRR & Annualized ROI.
  This can be expected in an incrementally growing Ridership.
- In contrast deployment of a full vehicle fleet servicing the maximum possible ridership from Day 1 of operations yields an even higher FIRR, Equity IRR & Annualized ROI.
  This can be expected in a high demand density scenario from Day 1 of Operations.
- Additional vehicles procured from project accruals (cash and reserves) only marginally affect the overall Rates of returns vis-à-vis from borrowed capital.

Case	FIRR	Equity IRR	A ROI
Standard Optimal Model with Incremental Fleet & Ridership (INR 11 / Km for Passenger Trips)	26.3%	24.4%	11.6%
Standard Optimal Model with Full Fleet & Incremental Ridership from Day1 of (INR 11 / Km for Passenger Trips) Operations	17.9%	16%	10%
Standard Optimal Model with Full Fleet & Full Ridership from Day1 of (INR 11 / Km for Passenger Trips) Operations	59%	61%	12%
Standard Optimal Model without Borrowings for Additional Fleet in Y12 & Y22 (INR 11 / Km for Passenger Trips) Operations	25.8%	23.8%	11.6%

System for Passenger and Goods Transport 24 Hrs. Operation	FIRR	Equity IRR	A ROI
Standard Optimal Model with Incremental Fleet (INR 11 / Km for Passenger Trips & INR 50 / Tonne Km for goods)	84.7%	91.0%	18.6%
Standard Optimal Model with Full Fleet & Incremental Ridership from Day 1 of Operations (INR 11 / Km for Passenger Trips & INR 50 / Tonne Km for goods)	72.16%	78%	17%
Standard Optimal Model with Full Fleet & Full Ridership from Day1 of (INR 11 / Km for Passenger Trips & INR 50 / Tonne Km for goods)	199%	201%	19%
Standard Optimal Model without Borrowings for Additional Fleet in Y12 & Y22 (INR 11 / Km for Passenger Trips & INR 50 / Tonne Km for goods)	89.3%	95.8%	18.6%

Table 39: FIRR, Equity IRR & AROI for Different Scenarios of Borrowed capital, Incremental Fleet & Ridership Vs Full Fleet & Ridership

2. Economic Returns

Economic benefits are social and environmental benefits that are quantified and then converted into monetary costs and compared to the cost of construction and maintenance for deriving the Economic Internal Rate of Return (EIRR). When actual revenue earned from fare collection, advertisement, and property development are discounted against construction and maintenance cost, interest (to be paid), and depreciation cost, the Financial Internal rate of Return (FIRR) is obtained. Therefore, EIRR is viewed from a socio-economic angle while FIRR is an indicator of pure financial profitability and viability of any project.

This computation is contextual to the deployment area and the computation of derived benefits from the system from several points of view like construction and maintenance costs, vehicle operating cost, road vehicle maintenance costs, the value of user time saved by system users, value of road user time savings, value of alternative fuel saved, savings from accidents, savings in pollution, etc.

For the most part, key metrics for offsetting the cost of a transportation infrastructure project are the value of time savings by equivalent users of the infrastructure, fuel savings cost, vehicle maintenance cost, and Environmental benefit from emission reduction, accident reduction, and road maintenance costs, all of which cannot be represented reasonably in the absence of contextual data.

E. Exploring Haridwar Pod Taxi (PRT) System Project

Extending the discussion, it is useful to compare the Financial & Economic feasibility of the AutoBots system as an alternative suitable candidate, in the context of a live project requirement.

Assuming all externalities, constraints, regulatory, funding pattern, project format, and environmental requirements for the Haridwar Pod Taxi Project to be the same, the key metrics for comparison can be reduced to computations for FIRR and Equity IRR when AutoBots as an alternative candidate is considered.

Another good metric can be AROI as an indicator of investment attractiveness for any investor.

This section reports the computations for the above metrics assuming the same constraints and datasets that DMRC has used to publish its recommendations for the aforesaid project, the basis on which UKMRCL further published its EOI cum RFQ towards its procurement process.

1. Context

Uttarakhand Metro Rail Corporation (UKMRCL), a special purpose vehicle of the State of Uttarakhand failed to conclude the first round of the procurement process For the Pod Taxi project named 'Haridwar Darshan', vide Tender Reference No: UM-140/EOI cum RFQ PRT Haridwar/2020-21/01 in November 2020 to conclude in April 2021, where UKMRCL had proposed to build a 19.65 km network of 4 elevated corridors on the central verge of the city's roads:

- Sitapur – Bharat Mata Temple: 14.0 km
- City Hospital – Daksha Temple: 3.0 km
- Ganeshpuram – DAV School: 2.0 km
- Valmiki Chowk – Laltaro Bridge: 0.65 km

This was because of a single bid issue. PNC Infratech emerged as the only firm to apply for developing Haridwar's Personalised Rapid Transit (PRT) system on a public-private partnership mode under Design, Built, Finance, Operate, and Transfer (DBFOT) basis.

A second Expression of Interest (EOI) for the Development of a Personalised Rapid Transit (PRT) System in Haridwar city of Uttarakhand called "Haridwar Darshan" under Design Built Finance Operate and Transfer (DBFOT basis) – (PPP MODEL) Vide Tender reference No: UM-140/EOI cum RFQ PRT Haridwar/2021-22/01 was re-issued by Urban Infrastructure & Building Construction Corporation Ltd. (UKMRCL), a PPP Project aimed towards International Competitive bidding process in April 2021 to conclude in June 2021.

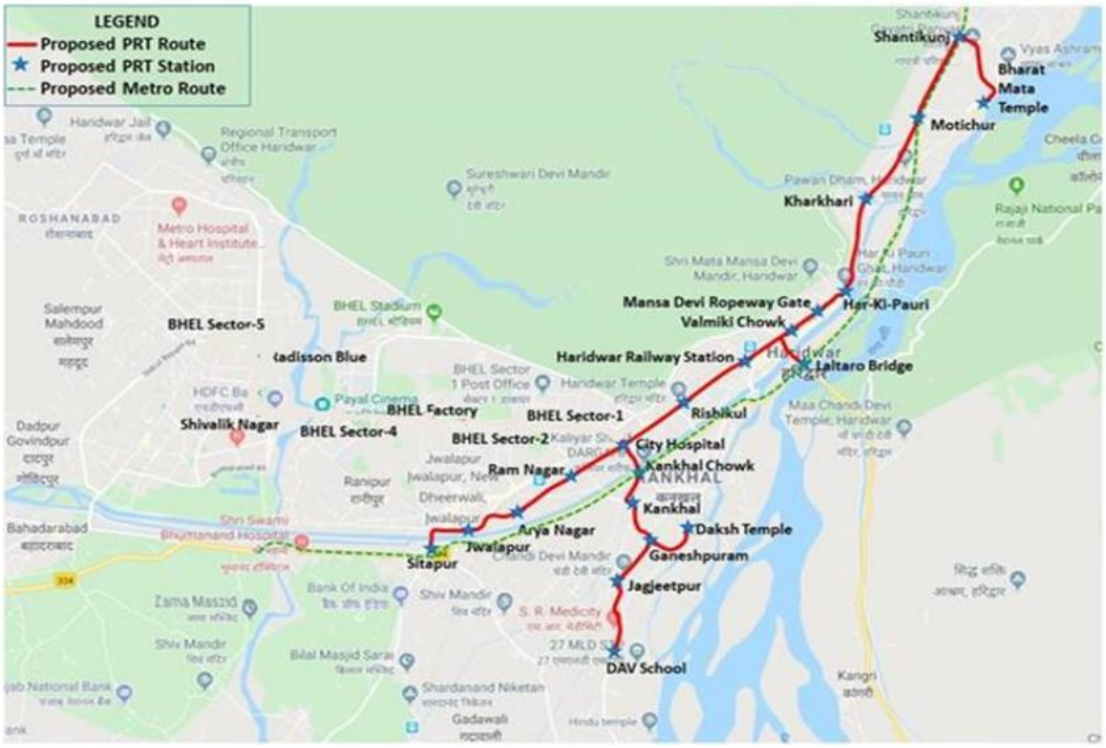


Figure 4: Proposed PRT corridors in Haridwar city

2. Detailed Project Report

A revised detailed project report (DPR) was commissioned to Delhi Metro Rail Corporation (DMRC) by Uttarakhand Metro Rail. Urban Infrastructure & Building Construction Corporation Ltd. (UKMRCL), for a Detailed Project Report for Personal Rapid Transit (PRT) System in Haridwar (Uttarakhand). The formal report was submitted as finalized in June 2021.

ICRA Analytics Ltd. Was appointed by the Delhi Metro Rail Corporation Limited (DMRC) to carry out the study for the project titled “Traffic and Transportation Study for Preparation of DPR for PRT System in Haridwar City” which submitted a final report formally in July 2021.

This DPR included a fresh thought on the ridership and an extended new alignment more suitable for the initiative.

3. Salient Features (Quoted)

a. Track Guideway

Minimum 4.2 m width for accommodating two PODs running in both directions.

b. Traffic Forecast

Parameters	2021	2031	2041	2051
Section Length (in km)	20.74	20.74	20.74	20.74
Daily Ridership including Induced Traffic on Normal	81,641	1,27,917	1,69,828	2,18,317

Day				
Average Trip Length including Induced Traffic on Normal Day (in km)	3.89	3.89	4.45	4.49
Daily Ridership on Mela (Poornima) Day	1,89,057	2,66,470	3,52,839	4,56,749
Average Trip Length for Mela (Poornima) Day (in km)	3.23	3.50	3.99	4.03
Weighted Average Daily Ridership with Induced Traffic	1,03,712	1,56,387	2,07,433	2,67,310
Weighted Average Trip Length with Induced Traffic (in km)	3.75	3.81	4.36	4.40

Note - Weighted Average Daily Ridership of the PRT system in Haridwar has been calculated by considering 75 Mela Days and 290 Normal Days in a Year.

Table 40: Traffic Forecast as per DMRC DPR

c. System Design (PRT)

POD Dimensions

Length	3500 mm to 4000 mm
Width	1400mm to 2000 mm
Height	1800 mm to 2400 mm

Designed- Passenger Loading

POD carrying capacity	6 passengers

Weight (kg)

Tare weight (minimum)	As Low as possible
Gross weight	Tare Weight + Weight of 6 passengers

Speed

Design Speed	100 kmph
Operating Speed (Maximum)	90 kmph
Average Speed	40 ~60 kmph

d. Power Demand Estimation

PRT Corridors	Load	Total Power Consumption (Year)				
All 4 Corridor total power Demand	AUX.	2021	2025	2031	2041	2051
		7.0 MW	7.0 MW	7.0 MW	7.7 MW	8.5 MW

e. Maintenance facilities

Maintenance Depot is planned at Rishikul.

f. Signaling, Tele-Communication & PRT Control

1. The Signaling system shall be designed to provide the highest level of safety & security along with efficiency in PRT services/operations. It consists of the following functions:

    - Central control

- Autonomous Vehicle Control (AVC)
- Automatic Vehicle Protection System (AVP)

2. Telecommunication System

   The communication system handles the transmission of critical control and status messages and the exchange of other information between the control system and PRT vehicles. The communications system is a vital part of the PRT operation, delivering routing and scheduling instructions to the vehicles from a central control center, and communicating their progress and status back to control. For communication among vehicles as well as with the elements of the network infrastructure (stations, intersections, etc.) the wireless communication system is used. Therefore, the control structure of PRT is a complex, distributed, real-time system.

g. Estimated Cost Including All Taxes & Land Cost

As per June 2021 price level, the total estimated cost including all taxes and land costs is Rs. 1,419 Crore.

h. Completion Cost Including All Taxes & Land Cost

Completion by October 2025

1. SPV Model: Rs. 1,612 Crores (IDC Rs. 19 Crore)
2. PPP(DFBOT): Rs. 1775 Crores (IDC Rs. 182 Crore)

i. Financial Indices

1. Financial Internal Rate of Return (FIRR): 16.16 % and 16.85% with and without PD Income from 10 ha. Land.
2. Economic Internal Rate of Return (EIRR): 11.71%

4. DPR Contents

0.1 Background

0.2 Travel Demand Forecast

0.3 Mass Rapid Transit Modes and Mode Choice

0.4 Civil Engineering and Geometric Design Parameters and Alignment Description

0.5 Station Details

0.6 Operation Plan, Depot & Maintenance Facilities

0.7 Power Requirements

0.8 Signaling and PRT Control System

0.9 Disabled Friendly Features

0.10 EIA and SIA Study for the PRT System

0.11 Security Measures

0.12 Disaster Management Measures

0.13 Multi-Modal Traffic Integration at PRT Station

0.14 Transit-Oriented Development

0.15 Cost Estimate

0.16 Financing Plan

0.17 Economic Appraisal

0.18 Implementation Plan

0.19 Conclusion and Recommendation

5. Conclusions (Quoted)

DMRC conclusions in two parts quoted as under. The portions relevant to this report have been italicized.

a. General

Public Transit Projects are highly capital-intensive on account of the high costs involved. Due to the need to maintain a fare structure within the affordable reach of ordinary citizens, Transit projects are ordinarily not financially viable. However, Haridwar is the gateway city of Uttarakhand and the Yoga Capital of the world thousands of domestic and international tourists visit the city annually. There is no organized, safe, reliable, secure, comfortable, and efficient mode of Public Transit available in the city. People are largely depending upon cycle rickshaws, e-rickshaws, autorickshaws, and Vikrams for commuting. ***Which is neither cost-effective nor comfortable.***

Considering the economic growth of the city implementation of the ***PRT System on selected four corridors is strongly recommended***.

The proposal for the corridors is technically feasible but involves the acquisition of land as well as the rehabilitation of some shops. This is a socio-economic problem and has to be tackled for the execution of the project.

Estimated Cost of the project at June 2021 price level is ₹1,419 Crore with all the taxes & duties and land costs. Whereas, Completion Cost (by Sept 2025) works out to ₹1,593 Crore excluding IDC.

The project has many positive environmental impacts like reduction in traffic congestion, saving in travel time, reduction in noise pollution, lesser fuel consumption, lesser road accidents, etc, with a few negative impacts (especially during the implementation phase of the project) for which Environmental Management Plan has been suggested.

After examining the various options for the execution of the project, it has been recommended that the project should be got executed through a concessionaire on PPP (DFBOT) mode.

The fare structure has been prepared based on a primary survey conducted in Haridwar. Subsequently, for the purpose of assessing returns from the project, the fares have been revised each year with an escalation of 5%.

b. Financial Internal rate of return (FIRR) and Economic Internal Rate of return (EIRR)

The Financial Internal Rate of Return (FIRR) for the project with central taxes has been assessed as 16.16% and 16.85% with and without PD.

The *Economic* Internal Rate of Return (EIRR) at the present rate works out to 11.71%. It seems to be on the lower side, as a major portion of modal shift passengers in the PRT system is from Cycle Rickshaw & E-rickshaw etc and their contribution to economic benefits is very small. Meanwhile, the State Government should freeze all future developments along the proposed corridors to avoid infructuous expenditure. To avoid delays in processing the clearance for the Project, UKMRC Board should approve the project on receipt of the DPR and forward the DPR to the Government of Uttarakhand, advising to take up the Project on DFBOT Model as recommended in Financial Analysis.

F. System Requirements as per DPR

1. Proposed System Requirements

Key requirements relevant to any Pod System costing for CAPEX, OPEX, and Income to formulate a Cash flow model (for comparative purposes) are as follows:

Length of Route ~20 Km Bi-directional

Traffic Demand Peak Hour 2051

Parameters	2051
Section Length (in km)	20.74
Daily Ridership including Induced Traffic on Normal Day	2,18,317
Average Trip Length including Induced Traffic on Normal Day (in km)	4.49
Daily Ridership on Mela (Poornima) Day (in km)	4,56,749
Average Trip Length for Mela (Poornima) Day	4.03
Weighted Average Daily Ridership with Induced Traffic	2,67,310
Weighted Average Trip Length with Induced Traffic (in km)	4.40

Corridors

S. No.	PRT Corridors	Route Length (km)	Station details
1	Corridor 1 | Sitapur to Bharat Mata Temple	14.55	14 Stations with two interchanges
2	Corridor 2 | City Hospital to Daksh Temple	3.10	4 Stations with two interchanges
3	Corridor 3 |Valmiki Chowk to Laltaro Bridge	0.69	1 Station with one interchange
4	Corridor 4 | Ganeshpuram to DAV School	2.40	2 Stations with one interchange

	Daily Ridership including Induced Traffic on Normal Day	Average Trip Length including Induced Traffic on Normal Day (in km)	Daily Ridership on Mela (Poornima) Day	Average Trip Length for Mela (Poornima) Day (in km)	Weighted Average Daily Ridership with Induced Traffic	Weighted Average Trip Length with Induced Traffic (in km)
2021	81641	3.89	189057	3.23	103713	3.64
2031	127917	3.89	266470	3.50	156387	3.75
2041	169828	4.45	352839	3.99	207433	4.29
2051	218317	4.49	456749	4.03	267310	4.33

Table 41: Year Wise Traffic Demand | Trip lengths | Weighted Averages

Year	Corridor	Route Length (km)	Normal 290 days Daily Ridership (Passengers)	Average Trip Length/ Passenger Lead (km)	Daily Ridership (Passengers)	Average Trip Length/ Passenger Lead (km)
2021	Sitapur - Bharat Mata	14.55	54,608	5.03	125059	4.1
2021	City Hospital - Daksh	3.11	16,295	1.65	33,766	1.66
2021	Valmiki Chowk - Laltaro	0.69	3,723	0.65	13,412	0.65
2021	Ganeshpuram - DAV School	2.38	7,015	1.9	16,821	1.98
			81,641	**3.89**	**189,058**	**3.23**
2031	Sitapur - Bharat Mata	14.55	84,449	5.08	171530	4.57
2031	City Hospital - Daksh	3.11	26,671	1.64	52,457	1.65
2031	Valmiki Chowk - Laltaro	0.69	5,612	0.65	16,656	0.65
2031	Ganeshpuram - DAV School	2.38	11,185	1.92	25,827	1.98
			127,917	**3.89**	**266,470**	**3.50**
2041	Sitapur - Bharat Mata	14.55	112558	5.74	228185	5.14
2041	City Hospital - Daksh	3.11	35,642	2.06	69,355	2.08
2041	Valmiki Chowk - Laltaro	0.69	7,256	0.65	21,752	0.65
2041	Ganeshpuram - DAV School	2.38	14,372	2.24	33,547	2.32
			169,828	**4.45**	**352,839**	**3.99**
2051	Sitapur - Bharat Mata	14.55	145939	5.78	297100	5.18
2051	City Hospital - Daksh	3.11	45,574	2.02	89,220	2.06
2051	Valmiki Chowk - Laltaro	0.69	9,393	0.65	28,337	0.65
2051	Ganeshpuram - DAV School	2.38	17,412	2.28	42,092	2.36
			218,318	**4.50**	**456,749**	**4.03**

Table 42: Year Wise Route Wise Ridership | Trip Lengths

Stations Peak Daily Demand 2051 (Poornima Mela Day)

UP Direction[6]

	Station Name	Daily Boarding	Daily Alighting	PHPDT (10% of Daily Traffic + 2% Surge Factor)	No of Bays Proposed	Passenger Handling per Bay/Hr	Total Capacity Per Hr	Remarks
Corridor 1: Sitapur to Bharat Mata Temple (14 Stations including one interchange)								
1	Sitapur	6907	0	829	6	360	2160	OK
2	Jwalapur	16485	400	1978	12	360	4320	OK
3	Arya Nagar	18109	1013	2173	12	360	4320	OK
4	Ram Nagar	7173	923	861	12	360	4320	OK
5	City Hospital	86497	4387	10380	16	360	5760	Severe Space

[6] DMRC DPR erroneously has not considered the DOWN direction at all to work out the total number of Bay requirements.

								constraint
6	Rishikul	18958	7213	2275	8	360	2880	OK
7	Haridwar Trackway Station	24626	22414	2955	12	360	4320	OK
8	Valmiki Chowk	18013	21350	2562	7	360	2520	Space constraint
9	Mansadevi Ropeway Gate	4398	41599	4992	14	360	5040	OK
10	Har-Ki-Pauri	1318	22920	2750	14	360	5040	OK
11	Kharkhari	501	3382	406	12	360	4320	OK
12	Motichur	630	15745	1889	6	360	2160	OK
13	Shantikunj	86	9478	1137	8	360	2880	OK
14	Bharat Mata Temple	0	987	118	8	360	2880	OK
Corridor 2: City Hospital to Ganeshpuram (Terminal) (5 Stations including one interchange)								
15	Kankhal Chowk	817	6729	807	8	360	2880	OK
16	Kankhal	387	8051	966	8	360	2880	OK
17	Ganeshpuram	18269	23086	2770	8	360	2880	OK
18	Daksh Temple	0	1250	150	8	360	2880	OK
Corridor 3: Valmiki Chowk to Laltaro Bridge (2 Stations including one interchange)								
19	Lal Taro Bridge	0	14104	1692	6	360	2160	OK
Corridor 4: Ganeshpuram to DAV School (3 Stations including one interchange)								
20	Jagjeetpur	174	3945	473	8	360	2880	OK
21	DAV school	0	14368	1724	12	360	4320	OK
	Total	**223344**	**223344**		**236**	**Bays**		

Table 43: Y 2015 | Ridership UP Direction | Station Bay Requirement

Current Mode Share

Modes	Modal Split
Bus	5.90%
Cycle Rickshaw	2.40%
Car	21.30%
E-Rickshaw	11.60%
Two-Wheeler	38.50%
Shared Auto	20.30%

Revenue Streams — Fare-Box Collections
Property Rental, Advertising, Parking, etc

Manpower Costs — @ 30 persons per Km with escalation factor used for staff costs has been assumed at 9% per annum

OO & M Costs — Escalation at 5% per annum

Electricity Rate — INR 5 per Unit

Full Reserved — 11% of Trips

Trip Distribution

Distance (km)	Normal Days	Mela Days
0-2	15.20%	24.90%
2-4	13.00%	16.80%
4-6	16.70%	13.90%
6-8	26.00%	19.70%
8-10	14.70%	15.30%
10-14	11.40%	8.10%
>14	3.00%	1.30%

Fare Structure

Distance (km)	Rs.
0-2	20
2-4	40
4-6	60
6-8	75
8-10	80
10-14	85
>14	90

Mode Shift to PRT	Time	61%
	Cost	11%
	Time & Cost Basis (Aggregate)	28%

2. Costs Estimates & Assumptions by DMRC

a. Investment Cost

It has been assumed that the Government of Uttarakhand will provide the land worth Rs.90.86 crore on an estimated cost basis either free of cost or it shall provide Interest-Free Subordinate Debt of the equal amount against it. The Interest-Free Subordinate Debt is normally repayable in 5 equal installments after repayment of the Multilateral/Overseas Development Assistance Loan. The financial calculations here have been done with this assumption only. This follows from the DMRC DPR assumptions.

For the purpose of calculations, it is assumed no expenditure on all security-related components is required for the system. The estimated capital cost does not include charges towards capital expenditure on security such as the cost of weapons, barricades, hand-held devices, door detector machines, etc. The new system will be provided with shelter platforms and there is no provision for platform screen doors, AFC gates, X-ray, and Baggage Scanner. The ticket validators are likely to be installed inside the platforms with NCMC or other ticketing systems. The recurring cost towards salary and allowances of security personnel has also not been taken into account in the FIRR calculation since providing required security at stations shall be the responsibility of the State Police.

For the purpose of calculating the Financial Internal Rate of Return (FIRR), completion cost with taxes has been calculated by taking the escalation factor @5% p.a. on all items except land.

The taxes and duties consist of Custom Duty (CD) and Goods & Services Tax (GST). The project falls in the category of urban infrastructural space and the promoter is assumed to arrange relaxation from the Government for concessional custom duties through project imports and lower GST liability of 12% admissible to other Govt. infrastructure projects. The effective Customs Duty (CD) rate under the project import scheme, post-GST, works out to 24.49% {Basic CD @ 5.5%, IGST (CGST & SGST) @ 18%} on the imported portions. The GST rate on the supply of indigenously manufactured items and services has been considered @ 12% (CGST & SGST @ 6% each).

It is assumed that the construction work of the line will commence from Year 1 and is expected to be completed by Year 3 with Revenue Opening Date (ROD) Year 3.

The total completion costs duly escalated and shown below have been taken as the initial investment.

Financial Year	Cost at June 2021 Price Level including Taxes & Land cost	Completion Cost including Taxes & Land cost
Y 0	163.15	169.79
Y 1	561.73	616.20
Y 2	561.73	645.49
Y 3	132.86	161.49
Total	1419.47	1592.98

Table 44: Year-Wise Investment

b. Additional Investment

The total investment provided in the FIRR calculation towards the requirement of additional POD cars based upon projected ridership as well as completely replacing the existing rolling stock, the cost of which has been duly escalated @5% p.a.

With Taxes & Duties			
Year	No. of Cars	No. of charging stations	Amount
Y 12	2200	-	122
Y 22	3300	11	238

Table 45: Additional Investment from an increasing number of Cars

c. Operation & Maintenance (O&M) Costs

Staff Requirement	30 persons per Km Track	600 persons
Staff Costs	9% escalation YOY	
Maintenance Costs	General Repairs & Maintenance 5% escalation YOY	
Electricity Costs	INR 5 per Unit 5% escalation YOY	

Year	Staff	Maintenance Expenses	Energy	Total
Y1	41.30	9.19	5.80	56.29
Y2	90.03	19.29	12.17	121.49
Y3	98.14	20.26	12.78	131.18
Y4	106.97	21.27	13.42	141.66
Y5	116.60	22.33	14.09	153.02
Y6	127.09	23.45	14.79	165.33
Y7	138.53	24.62	19.84	182.99
Y8	151.00	25.85	20.84	197.69
Y9	164.59	27.14	21.88	213.61
Y10	179.40	28.50	22.97	230.87
Y11	195.54	29.93	24.12	249.59
Y12	213.14	31.42	25.33	269.89
Y13	232.33	32.99	26.59	291.91
Y14	253.24	34.64	27.92	315.80
Y15	276.03	36.38	29.32	341.73
Y16	300.87	38.19	30.78	369.84
Y17	327.95	40.10	38.61	406.66
Y18	357.46	42.11	40.54	440.11
Y19	389.63	44.21	42.57	476.41
Y20	424.70	46.43	44.70	515.83
Y21	462.92	48.75	46.93	558.60
Y22	504.59	51.18	49.28	605.05
Y23	550.00	53.74	51.75	655.49
Y24	599.50	56.43	54.33	710.26
Y25	653.46	59.25	57.05	769.76
Y26	712.27	62.21	59.90	834.38
Y27	776.37	65.32	74.09	915.78
Y28				
Y29				
Y30				
	8443.65	995.18	882.39	10321.22

Table 46: Operations and Maintenance Costs

d. Depreciation

Depreciation not being a cash outflow has not been taken in the FIRR calculations.

e. Replacement cost

The replacement costs are provided for meeting the cost on account of the replacement of equipment due to wear and tear. It is expected that only 25% of system equipment would require replacement after 15 years.

Year	Replacement Cost
Y 15	12

Y 20	147
Y 21	154
Y 25	19
Total	332

f. Revenues

The Revenue mainly consists of fare box collection and other incomes from property rental, advertisement, parking, etc. Allied revenue streams could be from onboard infotainment, Carbon Credits, and from power generation from Solar plants on the tracks.

Only fare box revenues have been considered here.

g. Fare Box

The Farebox collection is the product of projected ridership per day and applicable fare structure based on trip distribution at different distance zones.

h. Traffic

Haridwar city attracts additional tourists in certain periods/days of the year in which the Religious Fair (Mela) is organized (75 Days a year). The ridership of the PRT system is expected to increase substantially during these days.

Year	Corridor	Route Length (km)	Daily Ridership (Passengers)	PHPDT (Passengers)
2021	Sitapur - Bharat Mata Temple	14.55	145,939	4849
2021	City Hospital - Daksh Temple	3.11	45,574	2446
2021	Valmiki Chowk - Laltaro Bridge	0.69	9,393	471
2021	Ganeshpuram - DAV School	2.38	17,412	953
			218318	

Table 47: Daily Ridership UP Direction

i. Trip Distribution and Fare Structure

The trip distribution indicates the percentage of commuters who will travel in various distance zones. As the fare for each distance zone is different it has a bearing on the estimated revenue. The trip distribution has been worked out based on the average lead at the Road level which is shown in the Table below.

Further, it has been considered that 11% of passengers will travel with a reservation of full POD.

Distance in km	Normal Days	Mela Days	Rs.
0-2	15.20%	24.90%	20
2-4	13.00%	16.80%	40
4-6	16.70%	13.90%	60

6-8	26.00%	19.70%	75
8-10	14.70%	15.30%	80
10-14	11.40%	8.10%	85
>14	3.00%	1.30%	90
Total	100%	100%	

The fare structure for the FY 2025-26 is as tabulated with the fare structure escalated @5% p.a. in succeeding years.

j. Non-Fare Box Revenue

Non-fare box revenue from property business and advertisement has been considered in addition to the fare box revenues.

Land measuring 10 hectares approx. has been considered to augment revenue. The value of the proposed land parcel has been estimated to be Rs.100 crore which the Government of Uttarakhand will provide free of cost.

Non-fare box revenues have been discounted from the computations.

3. Financial Internal Rate of Return (FIRR)

DMRC DPR analysis suggests a FIRR of 16.85% without any Property Development Income with the following sensitivities concerning variations in CAPEX, Revenues, and O&M costs.

Capital Cost			
20% increase in capital cost	10% increase in capital cost	10% decrease in capital cost	20% decrease in capital cost
14.93%	15.83%	18.05%	19.46%
Revenues			
20% decrease in Fare Box revenue	10% decrease in Fare Box revenue	10% increase in Fare Box revenue	20% increase in Fare Box revenue
12.77%	14.93%	18.62%	20.27%
O&M Costs			
10% increase in O&M cost		10% decrease in O&M cost	
16.14%		17.54%	

Table 48: FIRR and Sensitivity Analysis

4. Financing Options

a. Alternate Models for Financing

- Special Purpose Vehicle under the State Government Control (Delhi Metro Rail Corporation (DMRC) /Bangalore Metro Rail Corporation (BMRC)/Chennai Metro Rail Corporation (CMRL)/Mumbai Metro Rail Corporation (MMRC), and
- Design, Finance, Built, Operate & Transfer (DFBOT)

b. DFBOT Model

The DPR recommends a DFBOT model of financing as per the following format since the yields and IRR are better than the SPV model of financing.

Sources of Funds	Amount (Rs/Crore)	% of contribution
Equity by Concessionaire	451	30%
Market Borrowings by Concessionaire	1051	70%
Sub-Total (A)	1502	100%
Land Cost to be borne by Govt of Uttarakhand	91	
Sub-Total (B)	1593	
IDC on Loan (to be borne by the concessionaire)	182	
Total Cost including IDC	1775	

Table 49: Summary of Funding Pattern

G. Commentary on DPR from DMRC

1. The DPR & Tender

DMRC has prepared a comprehensive and well-structured DPR incorporating all topics of concern. All assumptions and deliberations can be taken as valid from the project perspective.

While there are several formats of a PRT system being proprietary technology of respective companies across the world, DMRC has chosen a specific typology of a pod (4-6) seat and a specific pod dimension in the DPR. This may be because this format is the only commercially proven or mature PRT system technology available today.

Although, the tender is silent on the specificity of the pod system technology but does refer to the Pod format with 4-6 seat carriers as 'chosen'. It would make more sense to broaden the base of the technology system in terms of specifying the system capacity rather than specifying the pod capacity.

2. Critical Note on Station Bay Layouts

The DPR, however, is not consistent with the requirements of the number of boarding-alighting bays for the projection year 2051, recommended therein based on the analysis provided by ICRA (Survey and analysis sub-consultant), including and therefore the design of the station itself in terms of sizing and layout drawings. Only the UP direction boarding bays has been considered for the station's total no of berths planning. Refer section 5.3.12 of the DPR & Station layouts 5.2 to 5.21

- The number of bays needs to be ~2X the number of bays currently provided for, thereby requiring 2X the length of each station or going another level, by DMRC's own reasoning.
- This has serious consequences flowing into the financial calculations, FIRR, EIRR, and commercial feasibility as stands approved by DMRC on which the Public Tender is based upon.
- Besides once operational, the station design layouts as proposed will be completely ineffective in servicing the projected loads by ~50%, hence liability for Haridwar and the project's success eventually.

3. Cash Flow from Ridership

Besides the error on the total no of berths not provided for the DOWN direction, the total ridership is likely to be severely affected for 25% of the days every year (Poornima Mela Days), constrained by the limited boarding capacity offered for 1 high load station where the DPR reports a ~40% share of boardings by the projection year 2051. Only ~50% of this can be served with the no of berths proposed.
This reduction of ~5% more towards the projection year, has also not been duly not taken into account in the fare box collections and inflowing revenues in the cash flow table.

4. FIRR, Equity IRR Computations

DMRC has computed the FIRR considering a lower CAPEX (on account of half-stations). FIRR will

reduce if the correct station size is applied. For Equity IRR, consideration of depreciation and Taxes on Income has not been considered at all. For a DFBOT concessionaire as recommended, this would be significantly different with the consideration of the same to my understanding, unless there is a tax holiday granted from Govt of Uttarakhand, which is not clear.

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H. AutoBots System | Potential Alternative for Haridwar

This is a discussion on how the AutoBots system is not only technologically suitable as a competitor to any other PRT system but also exceeds the FIRR & EIRR estimates of the DPR several folds. This assumes all externalities like financial structuring and finance amount amounts, remain the same.

Although the Tender requirement suggests a specific pod dimension and a specific capacity, the same can be compensated for differently with the AutoBots system, with the primary objective of catering to the demand projections as assessed.

AutoBots system design is carefully denominated to serve a group size of not more than 2 persons at a time, simply to reflect the global group size human travel requirements where globally ~85% of the times humans travel within a group size of 2 persons. And ~15% of the time the group size is more than 2.

This is reflective of the well-known statistical fact of average group size in most cities being 1.1-1.3 (for a specific trip purpose) and probability calculations of finding more than 2 persons in a travel group within the standard deviation formula is less than 15%.

5. Pod Capacity

AutoBots pod capacity is deliberately limited to 2 seats. This espouses several advantages to the system design.

- Reduction in the width of the pod means just 1.2m aerial RoW for each track, therefore system capacity can be added incrementally for the same aerial RoW provided, against a min. 4.2 m required for 4-6 seat systems.
- Reduction in pod weight load means a reduction of the depth of any beam by its 2nd power, therefore proportional reduction in CAPEX employed.
- Reduction in the size of the supporting column of any standard column by its 4th power, therefore a proportional reduction in CAPEX employed.
- No ride matching requirement for ~85% of travel groups, which otherwise is a necessity for larger seat vehicle carriers for each origin-destination pair. Ride matching results in substantially larger waiting for each passenger. (E-rickshaws / Vikram phenomenon even along the same route)
- With lesser wastage of available capacity (forced time-limited departures even if the pod is not full) a higher capacity utilization (~65-70%) can be expected. In the case of 4-6 seat pods, ~45% capacity utilization has been predicted. (Development of “Personal Rapid Transit (PRT) System at Amritsar (Punjab)” on Public Private Partnership format through Swiss Challenge Mode)
- Lower power requirements for acceleration and decelerations, therefore a reduction in the power ratings of each power train, therefore a reduction in CAPEX.

6. Satisfying Capacity Requirements

The AutoBots system by design employs several strategies to increase its system capacity for many

different application areas and demand requirements.

- Deploying 2 sets of tracks, parallel to each other doubles the design capacity as well as the productive capacity of the given same route. The same can be achieved at 2 levels as well only consuming 1.2 m of aerial RoW.
- Physical Linking of Pods using a mechanical coupler, so that the same can service 4 passengers at the same time while still retaining the same headway and/or frequency between pods.
- Increase the total number of berths at the station to cater to more boarding and alighting.
- Idle parking of empty vehicles at the station itself instead of a distant parking depot for rapid availability of extra vehicles whenever required.

7. AutoBots Technology System Features

Pod Capacity	2 Pax Groups (Pod Electronically linked for groups >2 Pax)
Pod Dimensions	Internal 1.8 m x 0.9 m External 2.4 m x 1.0 m
Pod Speed	Min 45Km/Hr Max 100 Km/Hr
Pod Frequency	2s
Pod Headway	25m
Pod Boarding Alighting	120/pod / Hr | 30s per Group (Door Opening (5s), Alighting + Boarding (20s), Door Close (5s) time)
Braking Distance	~22.5m
Max. Line Capacity	3600 Phpdt

8. AutoBots System | Assumptions for Haridwar

Tracks	2 lines -2.5 m Aerial RoW	(1.2 m wide per Line)
Support Pillars	80 Units per 100 m	(12.5 m interspacing)
Stations	26 Units	(13 per Line)
Station Footprint	3m x 5m per Bay	Bays layout in ‘File’ formation
Passenger Handling	Peak Daily Demand 2051 (Poornima Mela Day)	

UP Direction

	Station Name	Daily Boarding	Daily Alighting	Daily Section Load	Peak Hr Section Load PHPDT (10% of Daily + 2% Surge Factor)	Lines in UP Direction	Line capacity	Line Capacity Offered	Per Hr Boarding Capacity Required	Per Hr Alighting Capacity	Per Hr Boarding + Alighting Capacity	Passenger Handling per Bay/Hr	No of Bays Proposed	Total Capacity Per Hr Provided
Corridor 1: Sitapur to Bharat Mata Temple (14 Stations including one interchange)														
1	Sitapur	6907	0	6907	829	1	2700	2700	484	0	484	240	3	720
2	Jwalapur	16485	400	22992	2760	2	2700	5400	1154	28	1154	240	5	1200
3	Arya Nagar	18109	1013	40088	4811	2	2700	5400	1268	71	1268	240	6	1440
4	Ram Nagar	7173	923	46338	5561	3	2700	8100	503	65	503	240	3	720
5	City Hospital	48714	4387	90665	10880	5	2700	13500	3410	308	3410	240	15	3600
6	Rishikul	18958	7213	102410	12290	5	2700	13500	1328	505	1328	240	6	1440
7	Haridwar Trackway Station	24626	22414	104622	12555	5	2700	13500	1724	1569	1724	240	8	1920
8	Valmiki Chowk	3905	21350	87177	10462	4	2700	10800	274	1495	1495	240	7	1680
9	Mansadevi Ropeway Gate	4398	41599	49976	5998	3	2700	8100	308	2912	2912	240	13	3120
10	Har-Ki-Pauri	1318	22920	28374	3405	2	2700	5400	93	1605	1605	240	7	1680
11	Kharkhari	501	3382	25493	3060	2	2700	5400	36	237	237	240	1	240
12	Motichur	630	15745	10378	1246	1	2700	2700	45	1103	1103	240	5	1200
13	Shantikunj	86	9478	986	119	1	2700	2700	7	664	664	240	3	720
14	Bharat Mata Temple	0	987	0	0	0	2700	0	0	70	70	240	1	240
Corridor 2: City Hospital to Ganeshpuram (Terminal) (5 Stations including one interchange)														
5	City Hospital	37783	0	37783	4534	2	2700	5400	2645	0	2645	240	12	2879
15	Kankhal Chowk	817	6729	31871	3825	2	2700	5400	58	472	472	240	2	2880
16	Kankhal	387	8051	24207	2905	2	2700	5400	28	564	564	240	3	2880
17	Ganeshpuram	129	23086	1250	150	1	2700	2700	10	1617	1617	240	7	2880
18	Daksh Temple	0	1250	0	0	0	2700	0	0	88	88	240	1	240
Corridor 3: Valmiki Chowk to Laltaro Bridge (2 Stations including one interchange)														
8	Valmiki Chowk	14104	0	14104	1693	1	2700	2700	988	0	988	240	5	1200
19	Lal Taro Bridge	0	14104	0	0	0	2700	0	0	988	988	240	5	1200
Corridor 4: Ganeshpuram to DAV School (3 Stations including one interchange)														
17	Ganeshpuram	18140	0	18140	2177	1	2700	2700	1270	0	1270	240	6	1440
20	Jagjeetpur	174	3945	14369	1725	1	2700	2700	13	277	277	240	2	480
21	DAV school	0	14368	0	0	0	2700	0	0	1006	1006	240	5	1200

DOWN Direction

	Station Name	Daily Boarding	Daily Alighting	Daily Section Load	Peak Hr Section Load PHPDT (10% of Daily + 2% Surge Factor)	Lines in DOWN Direction	Line capacity	Line Capacity Offered	Per Hr Boarding Capacity	Per Hr Alighting Capacity	Per Hr Boarding + Alighting Capacity	Passenger Handling per Bay/Hr	No of Bays Proposed	Total Capacity Per Hr Provided
Corridor 1: Sitapur to Bharat Mata Temple (14 Stations including one interchange)														
14	Bharat Mata Temple	956	0	956	115	1	2700	2700	67	0	67	240	1	240
13	Shantikunj	7459	93	8322	999	1	2700	2700	523	7	523	240	3	720
12	Motichur	15882	583	23621	2835	2	2700	5400	1112	41	1112	240	5	1200
11	Kharkhari	3775	450	26946	3234	2	2700	5400	265	32	265	240	2	480
10	Har-Ki-Pauri	24409	1124	50231	6028	3	2700	8100	1709	79	1709	240	8	1920
9	Mansadevi Ropeway Gate	34151	5677	78705	9445	4	2700	10800	2391	398	2391	240	10	2400
8	Valmiki Chowk	21971	4292	96384	11567	5	2700	13500	1538	301	1538	240	7	1680
7	Haridwar Railway Station	22082	24293	94173	11301	5	2700	13500	1546	1701	1701	240	8	1920
6	Rishikul	7291	17388	84076	10090	4	2700	10800	511	1218	1218	240	6	1440
5	City Hospital	5009	39596	49489	5939	3	2700	8100	351	2772	2772	240	12	2880
4	Ram Nagar	841	7841	42489	5099	2	2700	5400	59	549	549	240	3	720
3	Arya Nagar	1001	22820	20670	2481	1	2700	2700	71	1598	1598	240	7	1680
2	Jwalapur	465	13343	7792	936	1	2700	2700	33	935	935	240	4	960
1	Sitapur	0	7790	0	0	0	2700	0	0	546	546	240	3	720
Corridor 2: City Hospital to Ganeshpuram (Terminal) (5 Stations including one interchange)														
18	Daksh Temple	1348	0	1348	162	1	2700	2700	95	0	95	240	1	2879
17	Ganeshpuram	30349	119	31578	3790	2	2700	5400	2125	9	2125	240	9	2880
16	Kankhal	11194	346	42426	5092	2	2700	5400	784	25	784	240	4	2880
15	Kankhal Chowk	7214	1018	48622	5835	3	2700	8100	505	72	505	240	3	2880
5	City Hospital	0	48621	0	0	0	2700	0	0	3404	3404	240	15	3600
Corridor 3: Valmiki Chowk to Laltaro Bridge (2 Stations including one interchange)														
19	Laltaro Bridge	14232	0	14232	1708	1	2700	2700	997	0	997	240	5	1200
8	Valmiki Chowk	0	14232	0	0	0	2700	0	0	997	997	240	5	1200
Corridor 4: Ganeshpuram to DAV School (3 Stations including one interchange)														
21	DAV School	19430	0	19430	2332	1	2700	2700	1361	0	1361	240	6	1440
20	Jagjeetpur	4348	180	23598	2832	2	2700	5400	305	13	305	240	2	480
17	Ganeshpuram	0	23,598	0	0	0	2700	0	0	1652	1652	240	7	1680



Interchange Stations

Table 50: Sectional Ridership Loads and computation of Boarding-Alighting Bays for AutoBots.

	UP & DN Direction								
	Station Name	Lines in UP Direction	No of Bays Proposed UP Direction	Lines in UP Direction	Lines in DOWN Direction	No of Bays Proposed DOWN Direction	Lines in DOWN Direction	Total Bi-Directional Lines for UP & DOWN	Total Bays for UP & DOWN
Corridor 1: Sitapur to Bharat Mata Temple (14 Stations including one interchange)									
1	Sitapur	1	3	1	1	1	0	1	6
2	Jwalapur	1	5	2	1	3	1	2	10
3	Arya Nagar	1	6	2	1	5	1	2	12
4	Ram Nagar	1	3	3	1	2	2	3	6
5	City Hospital	3	15	5	2	8	3	5	30
6	Rishikul	1	6	5	2	10	4	5	20
7	Haridwar Trackway Station	2	8	5	1	7	5	5	16
8	Valmiki Chowk	1	7	4	2	8	5	5	16
9	Mansadevi Ropeway Gate	2	13	3	1	6	4	4	26
10	Har-Ki-Pauri	2	7	2	2	12	3	3	24
11	Kharkhari	1	1	2	1	3	2	2	6
12	Motichur	1	5	1	2	7	2	2	14
13	Shantikunj	1	3	1	1	4	1	1	8
14	Bharat Mata Temple	1	1	0	1	3	1	1	6
Corridor 2: City Hospital to Ganeshpuram (Terminal) (5 Stations including one interchange)									
5	City Hospital	2	12	2	2	9	0	2	24
15	Kankhal Chowk	1	2	2	1	4	3	3	8
16	Kankhal	1	3	2	1	3	2	2	6
17	Ganeshpuram	2	7	1	3	15	2	2	30
18	Daksh Temple	1	1	0	1	1	1	1	2
Corridor 3: Valmiki Chowk to Laltaro Bridge (2 Stations including one interchange)									
8	Valmiki Chowk	1	5	1	1	5	0	1	10
19	Lal Taro Bridge	1	5	0	1	5	1	1	10
Corridor 4: Ganeshpuram to DAV School (3 Stations including one interchange)									
17	Ganeshpuram	1	6	1	1	6	0	1	12
20	Jagjeetpur	1	2	1	1	2	1	1	4
21	DAV school	1	5	0	2	7	1	1	14
Total No of Boarding Alighting Bays									320

9. Passenger System Capacities in Year 2, Year 12 & Year 30

The forthcoming financial and economic analysis is based on the following system snapshots.

Length of Bi-Directional Route	20	km
Length of AutoBots Tracks	40	km
Operational Travel Speed	45	km/hr
Distance Headway	25	m
Time Headway	2	sec
Pods / km / direction	40	Nos.
Cost of One PRT vehicle	1000000	INR
No of Stations	21	Nos.
No of Stations 4 bays	80	Nos.
Cost of 4 Station Bay	6000000	INR
Vertical Supports @ 12.5m	1600	Nos.
Seat Capacity utilization	75%	
Vehicle Load Factor	60%	
Vehicle Lifespan (years)	10	years
Idle Pod Parking	760	Nos.
Parking Depot @ 4.5 Sqm/ Pod	3420	Sqm
Service Depot @ 20% of Depot	684	Sqm
Project Period (years)	30	years

Table 51: AutoBots System Features to Satisfy Demand at Haridwar

	2021	
PRT Units replaced 10 yearly	1000	Nos.
Capacity of Pods (persons)	2	Nos.
Average Trip Length (weighted average)	3.64	Km
Operating Hours/day (hrs)	16	hrs
No. of Veh trips / day	118590	trips
Total vehicle km / day	432000	Vkm
Seat Km Per day	864000	Skm
Seat Capacity Utilisation	648000	Pkm
Number of Pax Trips	177885	Trips
No of Vehicle Trips with Full Reservation @10%	17789	Veh Trips
No Of Vehicle Trips with Shared Ride	106731	Veh Trips
Total Veh Trips	124520	Veh Trips

	2031	
PRT Units replaced 10 yearly	1600	Nos.
Capacity of Pods (persons)	2	Nos.
Average Trip Length (weighted average)	3.75	Km
Operating Hours/day (hrs)	16	hrs
No. of Veh trips / day	184150	trips
Total vehicle km / day	691200	Vkm
Seat Km Per day	1382400	Skm

Seat Capacity Utilisation	1036800	Pkm
Number of Pax Trips	276225	Trips
No of Vehicle Trips with Full Reservation @10%	27623	Veh Trips
No Of Vehicle Trips with Shared Ride	165735	Veh Trips
Total Veh Trips	193358	Veh Trips

	2041	
PRT Units replaced 10 yearly	3200	Nos.
Capacity of Pods (persons)	2	Nos.
Average Trip Length (weighted average)	4.29	Km
Operating Hours/day (hrs)	16	hrs
No. of Veh trips / day	322296	trips
Total vehicle km / day	1382400	Vkm
Seat Km Per day	2764800	Skm
Seat Capacity Utilisation	2073600	Pkm
Number of Pax Trips	483444	Trips
No of Vehicle Trips with Full Reservation @10%	48344	Veh Trips
No Of Vehicle Trips with Shared Ride	290066	Veh Trips
Total Veh Trips	338411	Veh Trips

Culminating in a peak in 2051.

	2051	
PRT Units replaced 10 yearly	3200	Nos.
Capacity of Pods (persons)	2	Nos.
Average Trip Length (weighted average)	4.33	Km
Operating Hours/day (hrs)	16	hrs
No. of Veh trips / day	319372	trips
Total vehicle km / day	1382400	Vkm
Seat Km Per day	2764800	Skm
Seat Capacity Utilisation	2073600	Pkm
Number of Pax Trips	479058	Trips
No of Vehicle Trips with Full Reservation	47906	Veh Trips
No Of Vehicle Trips with Shared Ride	287435	Veh Trips
Total Veh Trips	335341	Veh Trips

Table 52: Deployment of PRT units commensurate to the growing demand.

10. Summary Ridership Capacities on Offer

Summary capacities on offer every 10 years have been computed as follows with respect to requirements.

	Daily Ridership including Induced Traffic on Normal Day	Average Trip Length including Induced Traffic on Normal Day (in km)	Daily Ridership on Mela (Poornima) Day	Average Trip Length for Mela (Poornima) Day (in km)	Weighted Average Daily Ridership with Induced Traffic	CAGR Ridership	Weighted Average Trip Length with Induced Traffic (in km)	Weighted Fare per Trip	CAGR Ridership
2021	81641	3.89	189057	3.23	103713	4.19%	3.64	58	4.2%
2031	127917	3.89	266470	3.50	156387	2.87%	3.75	94	2.9%
2041	169828	4.45	352839	3.99	207433	2.57%	4.29	152	2.6%
2051	218317	4.49	456749	4.03	267310		4.33	248	

Table 53: Weighted Average Ridership, Trip Length & Fare per Trip

Daily Ridership on Pods + Decadal CAGR of 5%	Cars		Daily Supply	Annual Supply	Daily Maximum Ridership on Mela Day	Weighted Average Daily Ridership with Induced Traffic	Annual Requirement	Annual Utilisation
Year Y2 to Y12	1000	Trips	177885	64928025	189057	103713	37855165	58%
Year Y12 to Y22	1600	Trips	276225	100822125	266470	156387	57081180	57%
Year Y22 to Y30	3200	Trips	483444	176457060	352839	207433	75713045	43%
Year Y30	3200	Trips	479058	174856170	456749	267310	97568105	56%

Table 54: Available capacity Every 10 Years with appended Fleet size

11. Costs Estimates & Assumptions

All assumptions regarding CAPEX Investment, additional Investment, Operation & Maintenance (O&M) Costs, Depreciation, Replacement cost, Revenues, Fare Box, Traffic, Trip Distribution, and Fare Structure & Non-Fare Box Revenue follow from the DMRC DPR.

Slightly different assumptions have been adopted concerning the following for the reasons as under.

a. Investments

Capacity augmentation strategies have been adopted to serve the same demand. Instead of 1 bi-directional track, 2 bidirectional tracks have been adopted for the entire alignment.

Some heavy load sections between a few stations may ideally require more capacity than some which require lesser capacity than 2 bi-directional tracks considered for the entire alignment.

AutoBots has the unique advantage of serving both higher load sections and lower load sections more effectively, by deploying only 1 bi-directional line where lower capacity is required and deploying 3-4 bi-directional lines wherever capacity requirements are larger.

The figure below explains which sections need 1 bi-directional line and which ones need multiples. AutoBots has the unique ability to be flexible enough by way of line capacity vis-à-vis other systems that need the line but do not need the capacity.

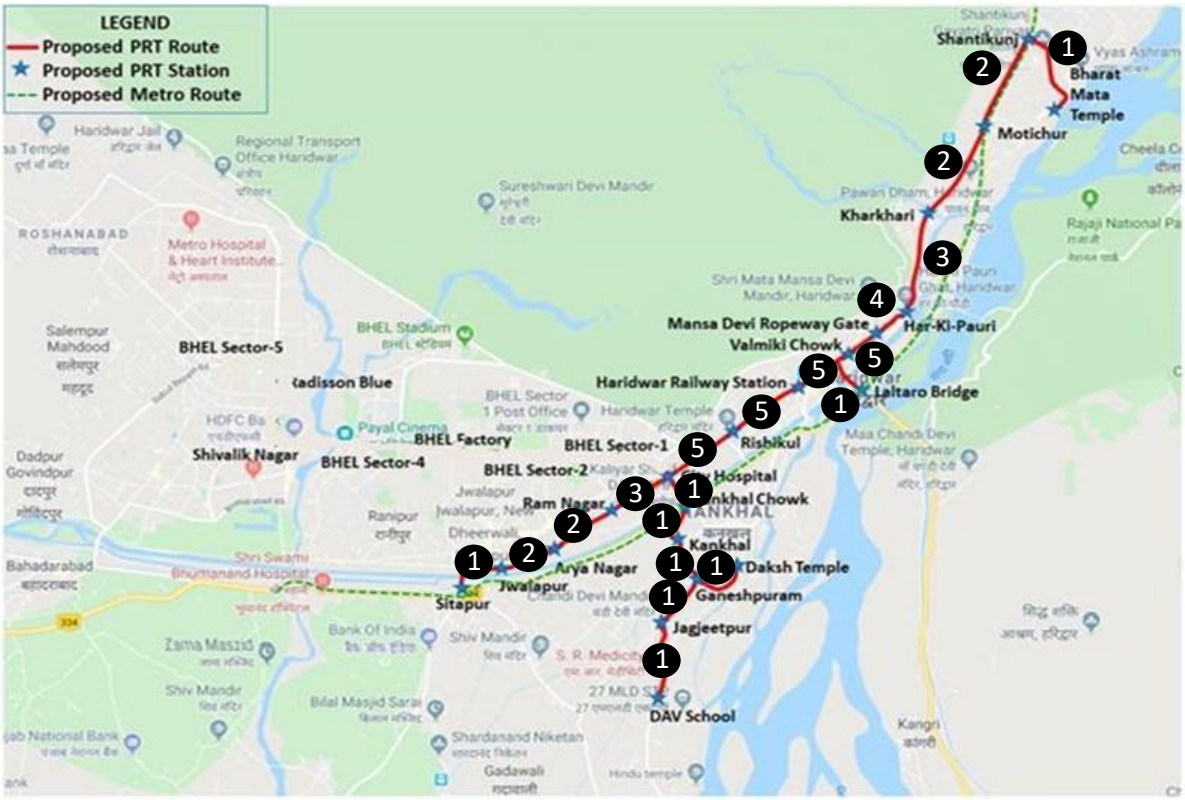

Figure 5: Number of Bi-directional AutoBots Lines required to service the Full Demand Y 2051

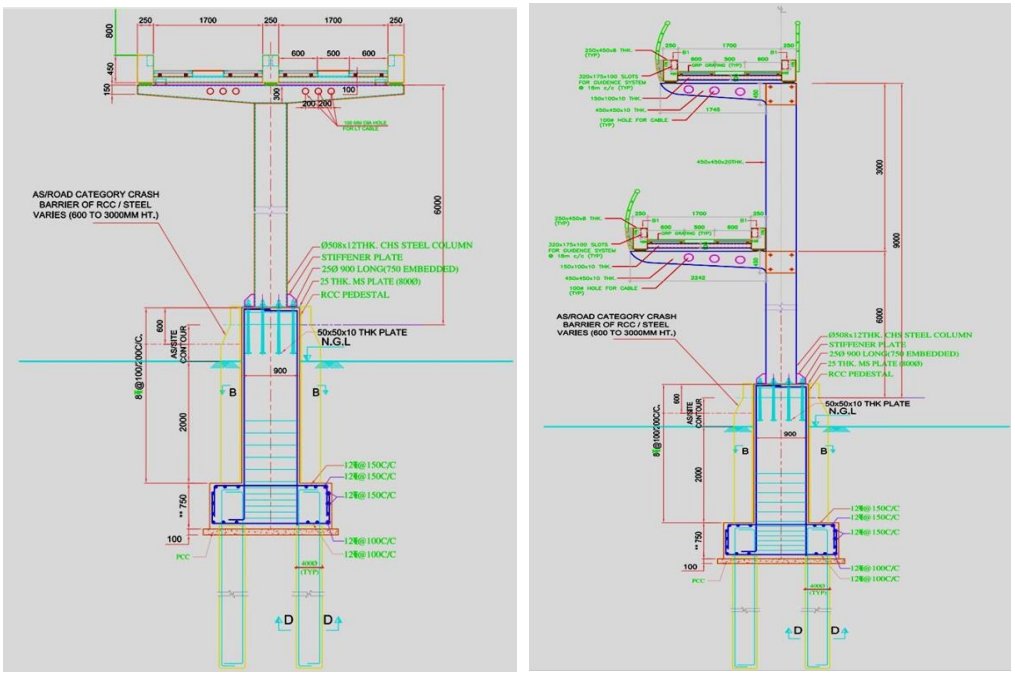

Figure 6: Typical Cross section of viaduct as per DMRC DPR

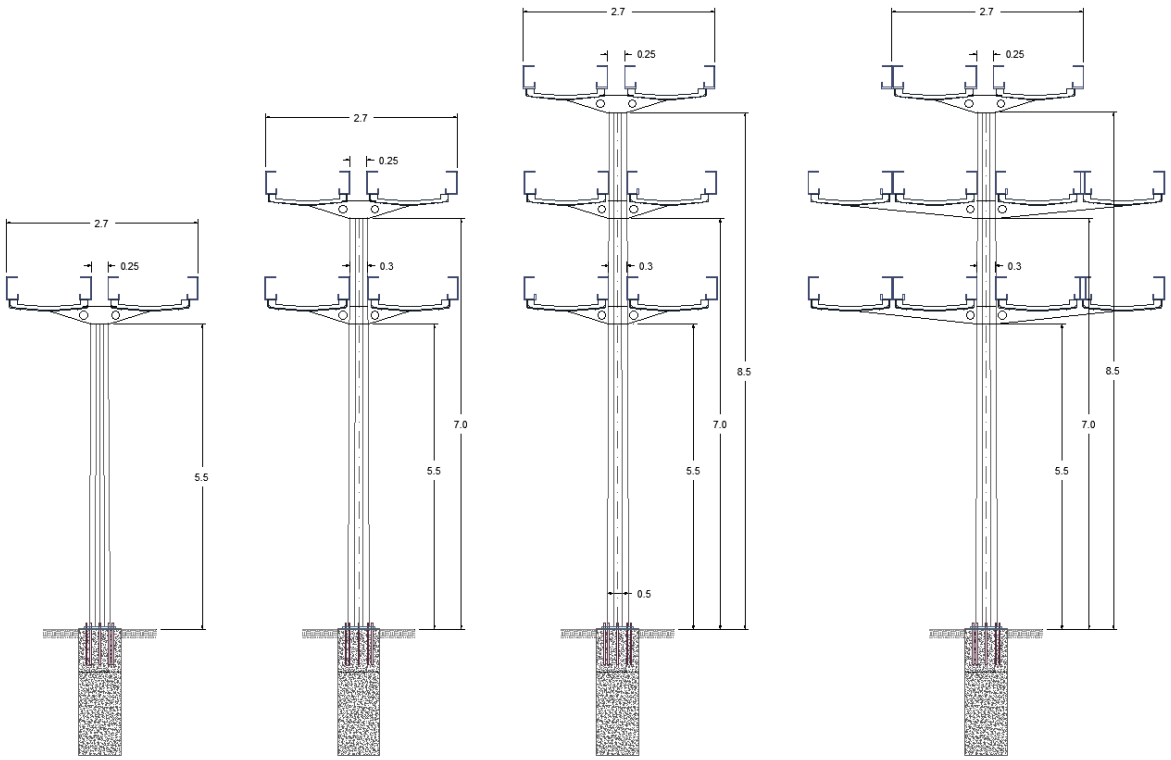

Figure 7: AutoBots 1, 2, 3, & 5 Bi-directional Viaduct Profiles as per the requirement of Loading Sections

With lighter and more efficient structural support methodology with AutoBots, the viaduct Profiles can be suited to specific loads in between Station sections - instead of a general single profile as suggested by the DMRC DPR, that could be underutilized.

Incremental addition or changes in load capacity can also be addressed when required. This strategy of reducing the denominator makes the overall structural costs of the system lower by a factor of ~2.

b. Additional Investments

The total number of vehicles deployed is different because of the seating capacity required YOY. However, the stock is augmented every 10 years to the required capacity by completely replacing the existing fleet, assuming a lifecycle of ~10 years for each vehicle.

12. Project Capital Expenses (CAPEX)

For a typical deployment time of 2 years, the CAPEX distribution would be as follows.

The investment is employed equally over the 2 pre-operative years. The station, guideway + track components, and pods consume the maximum investments (13%, 27%, and 44% respectively)

Cost of System Development	Units	Number	Rate	Total Cost (Cr)	Taxes
Company Affairs, Legal & System Sizing				0.90	
Planning Feasibility, Design & Detailing				5.00	
Land Related				5.57	
Land Cost	Sqm	2549	20000	5.10	

Depot Land for 4-storey Structure	Sqm	236	20000	0.47	
Civil & Structure				272.60	35.59
R&R + Utility Shifting	Km	20	10000000	20.00	2.40
Support Pillars	Nos	3200	30000	9.60	1.15
Guideway Cost	Km	80	10000000	80.00	9.60
Stations Bay Development Cost + MEP	Nos	80	6000000	48.00	5.76
OCC Development Cost + MEP	Nos	1	30000000	3.00	0.44
Traction Power Cost (Third Rail)	Km	80	4000000	32.00	4.64
Track Components	Km	80	10000000	80.00	11.60
Depot				38.23	4.59
Pod Idling Depot + MEP	Sqm	12744	30000	38.23	4.59
Control System				10.00	1.20
Operation Management Software	Unit	1	100000000	10.00	1.20
Pod Cost				100.00	14.50
Vehicle Unit Cost	Nos	1000	1000000	100.00	14.50
Total Cost without Land				427	56
General Costs @ 5%				21.3	
Contingencies @3%				12.8	
Total cost of all items including R&R, General Charges, and Contingency without land				**460.87**	**55.87**
				516.75 Cr INR	
Total cost of all items including R&R, General Charges, and Contingency with land				**466.44**	**55.87**
				522.32 Cr INR	

Table 55: Investment Schedule for full infrastructure and part rolling stock

Summarily this translates to

System Costs		
Planning & Design	0.30	Cr/Km
Technology System	21.0	Cr/Km
Technology System Cost + Taxes	23.8	Cr/Km
Technology System Cost + General Costs & Contingencies	23.0	Cr/Km
Technology System Cost + Taxes, General Costs & Contingencies	25.8	Cr/Km
Project Costs		
Land Costs	0.3	Cr/Km
Pre-Operation +R&R+ System Cost	23.0	Cr/Km
Pre-Operation +R&R+ System Cost +Taxes	24.4	Cr/Km
Pre-Operation +R&R+ System Cost +Taxes + GC + Contingencies	26.1	Cr/Km
All Costs	26.1	Cr/Km

Table 56: Summary of Costs per Km | Full Infrastructure & Part Rolling Stock

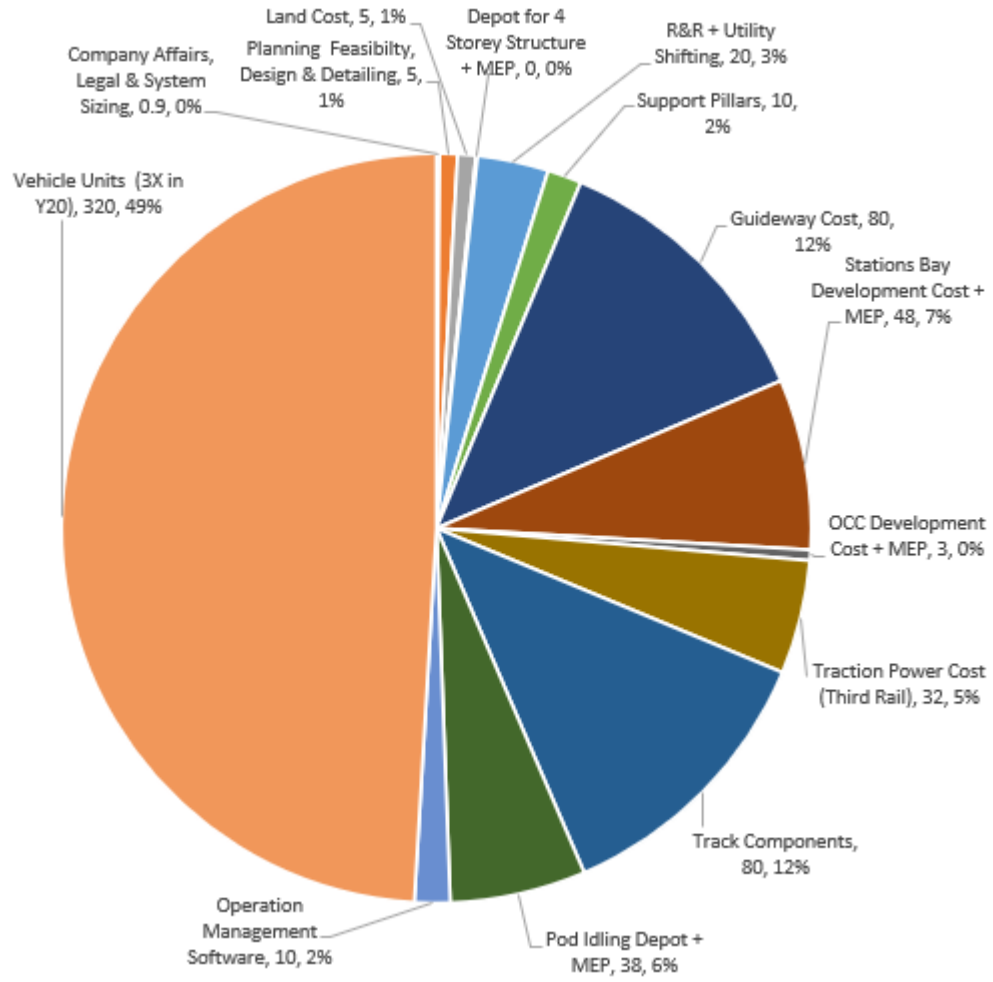

Figure 8: Apportionment of CAPEX in Percentage | Only Passenger Format

One can assume that only a third of the pods will be required for the first 10 years of the operation, completely replaced with twice the number in the 10 years of operation, and again completely replaced in the 20th year of operation.

The cash flow in the following section considers the deployment of only~ 33% of the rolling stock and ridership at the start of operations, assuming a pessimistic revenue flow consideration.

Alternatively, If the full fleet is deployed from day 1 of operations the comparison is as follows. This would result in non-operational vehicles and a wastage of supply capacity.

Cost of System Development	Units	Number	Rate	Total Cost (Cr)	Taxes
Company Affairs, Legal & System Sizing				0.90	
Planning Feasibility, Design & Detailing				5.00	
Land Related				5.57	
Land Cost	Sqm	2549	20000	5.10	
Depot Land for 4-storey Structure	Sqm	236	20000	0.47	
Civil & Structure				279.60	35.59
R&R + Utility Shifting	Km	20	10000000	20.00	2.40
Support Pillars	Nos	3200	30000	9.60	1.15

Guideway Cost	Km	80	10000000	80.00	9.60
Stations Bay Development Cost + MEP	Nos	80	6000000	48.00	5.76
OCC Development Cost + MEP	Nos	1	30000000	3.00	0.44
Traction Power Cost (Third Rail)	Km	80	4000000	32.00	4.64
Track Components	Km	80	10000000	80.00	11.60
Depot				38.23	4.59
Pod Idling Depot + MEP	Sqm	12744	30000	38.23	4.59
Control System				10.00	1.20
Operation Management Software	Unit	1	100000000	10.00	1.20
Pod Cost				320.00	46.40
Vehicle Unit Cost	Nos	3200	1000000	320.00	46.40
Total Cost without Land				649	88
General Costs @ 5%				32.4	
Contingencies @3%				19.5	
Total cost of all items including R&R, General Charges, and Contingency without land				**700.63**	**87.77**
				788.41 Cr INR	
Total cost of all items including R&R, General Charges, and Contingency with land				**706.20**	**87**.77
				793.98 Cr INR	

Table 57: Investment Schedule for full infrastructure and full rolling stock

Summarily this translates to

System Costs		
Planning & Design	0.30	Cr/Km
Technology System	64.4	Cr/Km
Technology System Cost + Taxes	68.8	Cr/Km
Technology System Cost + General Costs & Contingencies	35.0	Cr/Km
Technology System Cost + Taxes, General Costs & Contingencies	39.4	Cr/Km
Project Costs		
Land Costs	0.6	Cr/Km
Pre-Operation +R&R+ System Cost	35.0	Cr/Km
Pre-Operation +R&R+ System Cost +Taxes	37.1	Cr/Km
Pre-Operation +R&R+ System Cost +Taxes + GC + Contingencies	39.7	Cr/Km
All Costs	39.7	Cr/Km

Table 58: : Summary of Costs per Km | Full Infrastructure & Part Rolling Stock

13. Project Operational Expenses (OPEX)

a. Service Personnel Recurring Expense

Recurring cost on Service Personnel at 30 Nos per station and 640 Nos per BU and an additional ~19 Nos at the Depot and OCC as follows, amounting to INR ~1.5 Cr/Km annually

Recurring Cost at All Stations | System Wide	Units	Number	Monthly Rate	Annual Cost INR Crores
Security + Standby	120	35000	5.04	5.04
Supervisors + Standby	180	35000	7.56	7.56
Booth Manager + Standby	180	45000	9.72	9.72
Service Engineer	20	60000	1.44	1.44
Administration Misc	120	20000	2.88	2.88
Services - Electricity & Airconditioning	20	40000	0.96	0.96
Recurring Cost Central Depot | Operations Control Centre	Units	Number	Monthly Rate	Annual Cost INR Crores
Security	Nos	3	35000	0.126
Supervisors	Nos	3	35000	0.126
Booth Manager	Nos	3	45000	0.162
Service Engineer	Nos	1	60000	0.072
Accountant	Nos	2	40000	0.096
Administration Misc	Nos	3	60000	0.216
Services - Electricity & Airconditioning	Nos	2	40000	0.096
General Manager	Nos	2	240000	0.576

Table 59: Personnel Requirement and Cost Details

b. Energy Expenses | Passenger

Passenger Vehicle O& M Expense (Annual)	Units	Number	Rate	Annual Cost INR Crores
Pod Cars Year Y2 to Y12	KW	85147200	5.00	42.57
Pod Cars Year Y2 to Y22	KW	136235520	5.00	68.12
Pod Cars Year Y22 to Y30	KW	272471040	5.00	136.24
Cost of Maintenance @5% Cost Pod Fleet +5% YOY	Rs	3200000000	0.05	16.00
Infrastructure O&M (Annual) 16 Hrs				
Station Load for Station Berths at Station	Mil KW	5.01	5.00	2.50
Total Power load Requirement for Depot	Mil KW	1.68	5.00	0.84
Total power load Requirement for Station Lifts + Escalators	Mil KW	9.81	5.00	4.91

Table 60: Summary Costs of Energy Requirements

c. Technology License Fees Expense | Passenger

License Fees (Annual)				
Franchisee Fees for Route + 5% YOY	Km	80	1800000	14.40
Franchisee Fees for Pod Fleet @2% + 5% YOY	Veh	3200	72000	23.04
Application Software License Fee @10% + 5% YOY	%	10%	-	1.00

Table 61: Technology License Fees

14. Revenues

AutoBots deployments at Haridwar will be deployed as linear connections with a few fingers diverging from the main spine.

Revenue	Units
From Passenger Trips	Passenger trips/day
From Goods Transport	TonneKm/day
From Advertisements	Per station per day
In-Vehicle Entertainment Advertisement	Per 10 sec for 16 hrs
From Carbon Credits	tCO2e/day

This analysis discounts the revenue streams from goods haulage, advertisements, in-vehicle infotainments, and or carbon credits.

Distance (km)	Normal Days	Mela Days	Distance (km)	Rs. Normal Days	Rs. Mela Days
0-2	15.20%	24.90%	0-2	20	20
2-4	13.00%	16.80%	2-4	40	40
4-6	16.70%	13.90%	4-6	60	60
6-8	26.00%	19.70%	6-8	75	75
8-10	14.70%	15.30%	8-10	80	80
10-14	11.40%	8.10%	10-14	85	85
>14	3.00%	1.30%	>14	90	90
Average Weighted Fare per Trip				61.91	55.11

The weighted average fare for each trip of an ATL of 4.5 Km has been assumed to be INR 55 for Normal Day and INR 62 for Mela Day.

Ridership Normal (290 Days)	2021-2031	2031-2041	2041-2051	Weighted Average fare / Trip 2021 +5% YOY	Total Revenue Normal Days in INR Crores	Ridership Poornima (75 Days)	2021-2031	2031-2041	2041-2051	Weighted Average fare / Trip 2021 +5% YOY	Total Revenue Poornima Days in INR Crores	Total Annual Revenue for All Days in INR Crores
CAGR	4.6%	2.9%	2.5%	62		CAGR	3.5%	2.8%	2.6%	55		
Y1						Y1						
Y2						Y2						
Y3	23.7			62	147	Y3	14.2			55	78	225
Y4	24.8			65	161	Y4	14.7			58	85	246
Y5	25.9			68	177	Y5	15.2			61	92	269
Y6	27.1			72	194	Y6	15.7			64	100	295
Y7	28.3			75	214	Y7	16.3			67	109	322
Y8	29.6			79	235	Y8	16.8			70	118	353
Y9	31.0			83	258	Y9	17.4			74	128	386
Y10	32.4			87	283	Y10	18.0			77	140	422
Y11	33.9			92	311	Y11	18.7			81	152	462
Y12	35.5			96	341	Y12	19.3			85	165	506

Y13		37.1		101	375	Y13		20.0		90	179	554
Y14		38.2		106	405	Y14		20.6		94	193	598
Y15		39.3		111	437	Y15		21.1		99	209	646
Y16		40.4		117	472	Y16		21.7		104	225	698
Y17		41.5		123	510	Y17		22.4		109	243	754
Y18		42.7		129	551	Y18		23.0		114	263	814
Y19		44.0		135	595	Y19		23.7		120	284	879
Y20		45.2		142	643	Y20		24.3		126	307	949
Y21		46.5		149	694	Y21		25.0		132	331	1026
Y22		47.9		157	750	Y22		25.7		139	358	1108
Y23			49.3	165	810	Y23			26.5	146	386	1196
Y24			50.5	173	872	Y24			27.2	153	416	1288
Y25			51.8	181	939	Y25			27.9	161	448	1388
Y26			53.1	190	1011	Y26			28.6	169	483	1494
Y27			54.5	200	1089	Y27			29.3	177	520	1609
Y28			55.8	210	1172	Y28			30.1	186	561	1733
Y29			57.3	220	1262	Y29			30.9	196	604	1867
Y30			58.7	231	1359	Y30			31.7	205	651	2010

Table 62: Revenues from Fare Box

15. Financial Internal Rate of Return

The Financial Internal Rate of Return (FIRR) without any additional peripheral (PD, Advertisement, Infotainment, etc) income for 30 years life cycle business model including construction period works is tabulated as under.

		Total Revenue from Passenger Trips + 5% YOY	Total A Cost of System Deployment	Total B Source of Funds	Total C Recurring Cost + 5% YOY	Total Interest (D2)	Total Repayment (E)	F Cash flow Operations and CAPEX (A-C)	G Admin, Sales & Mgmt. Cost	H Operating Cash Flow (F - G)	Financial IRR
Pre-Operative	Y1		264	157		0		-264	0	-264	
	Y2		258	366		37	0	-258	0	-258	
Operations	Y3	225			134	40	40	90	2	88	
	Y4	246			141	32	113	105	2	103	
	Y5	269			147	24	105	122	3	119	-18%
	Y6	295			154	16	97	140	3	137	-5%
	Y7	322			162	8	88	161	3	157	4%
	Y8	353			169		80	183	4	180	10%
	Y9	386			177			209	4	205	14%
	Y10	422			186			237	4	232	17%
	Y11	462			195			268	5	263	20%
	Y12	506	261	261	206	26	26	40	5	35	20%
	Y13	554			219	21	73	334	6	329	21%
	Y14	598			229	16	68	369	6	363	23%

	Y15	646			239	10	63	407	6	401	24%
	Y16	698			249	5	57	449	7	442	24%
	Y17	754			310		52	443	8	436	25%
	Y18	814			271			543	8	534	25%
	Y19	879			283			596	9	587	26%
	Y20	949			296			654	9	644	26%
	Y21	1026			309			717	10	707	26%
	Y22	1108	849	849	332	85	85	-74	11	-85	26%
	Y23	1196			393	68	238	803	12	791	26%
	Y24	1288			409	51	221	879	13	866	27%
	Y25	1388			426	34	204	961	14	947	27%
	Y26	1494			444	17	187	1050	15	1035	27%
	Y27	1609			463		170	1146	16	1130	27%
	Y28	1733			482			1251	17	1234	27%
	Y29	1867			503			1364	19	1345	27%
	Y30	2010			524			1486	20	1466	27%
		24096	1632	1632	8053	490	1965	14411	241	14170	27%

Table 63: Cash Flows and Financial Rate of Return | Only Passenger Transport Format

16. Sensitivity

The various sensitivities concerning increase/decrease in capital costs, O&M costs, and fare-box revenues are placed as follows

Case		FIRR	Equity IRR	A ROI
Standard Optimal Model with Incremental Fleet & Ridership (INR 11 / Km for Passenger Trips)		27.0%	24.6%	17.0%
Scenario 1	1.5 X Infrastructure Cost +	17.6%	15.2%	14.3%
	1.5 X Personnel Cost			
Scenario 2	0.6 X Fare Box Revenue (INR 25 / Passenger Trip)	12.1%	10.0%	12.1%
	0.8 X Fare Box Revenue (INR 40 / Passenger Trip)	20.1%	17.7%	15.2%
Scenario 3	1.5 X Infrastructure Cost +	12.0%	9.8%	11.9%
	1.5 X Personnel Cost +			
	0.8 X Fare Box Revenue			
Standard Optimal Model with Incremental Fleet & Ridership (INR 11 / Km for Passenger Trips) **Without Depreciation & Income Taxes**		27.0%	30.5%	18%

Table 64: Sensitivity Analysis for Up to 50% increase in CAPEX +OPEX & upto 40% decrease in Fare Box Revenues

17. Financing Options

a. Special Purpose Vehicle

The corridors being standalone and, therefore, forming a separate SPV may be desirable. The

State Government can create an SPV for the planning and implementation of PRT systems in the State.

However, like all other SPVs (DMRC-Delhi, LMRCL-Lucknow, Kochi Metro-Kerala, BMRC-Bangalore, CMRL-Chennai, or MMRC-Mumbai) a high Capex Infrastructure project seems to be bogged down by a large equity component besides the State having to absorb all taxes on CAPEX. Although ODA Loan from a multi-lateral or bi-lateral institution is possible, such projects are generally subsidized for both CAPEX & OPEX.

Both FIRR and Equity IRR remain poorer than other alternatives like DFBOT in the longer term, with ODA loan interest & repayment period also lasting the entire project period.

b. DFBOT Model for Implementation

In the model, the private firm will be responsible for financing, designing, building, operating, and maintaining the entire project. This reduces the overall burden on the public exchequer in terms of equity contribution and or bearing applicable taxes.

However, Land may be provided by the Government Agency at no cost to the Concessionaire with the financing model dependent upon the selection of a dedicated agency to implement the project.

Apart from equity contribution from the promoters, it is assumed that the funding for the project shall be achieved through market borrowings. The rate of interest on market borrowings is assumed at 10% p.a. and the repayment of the loan will start immediately after the commercial operations and be repaid in 5 (Five) years.

Accordingly, the funding pattern proposed is placed as under:

Sources of Funds	Amount (Rs Crore)	% of contribution
Equity by Concessionaire	157	30%
Market Borrowings by Concessionaire	366	70%
Sub-Total (A)	522	100%
Land Cost to be borne Government Agency	0	
Sub-Total (B)	522	
IDC on Loan (to be borne by the Concessionaire)	37	
Total Cost including IDC	559	

Table 65: Funding pattern under DFBOT Model

18. Source of Funds, Interest, and Repayments

A mix of Equity from the Concessionaire & Debt Funds from a lending agency is assumed for the initial CAPEX expenditure to start operations. Replacement and additional vehicles every 10 years of operations are assumed to be procured using debt.

The revenues built up from operational income are assumed to finance all other OPEX during the operational period including the replacement of all electrical equipment in the 15th year.

	Stage 1 Equity	Stage 1 Debt	Stage 2 Equity	Stage 2 Debt	Stage 3 Equity	Stage 3 Debt	Total B Source of Funds
Y1	157						157
Y2		366					366
Y3							
Y4							
Y5							
Y6							
Y7							
Y8							
Y9							
Y10							
Y11							
Y12				261			261
Y13							
Y14							
Y15							
Y16							
Y17							
Y18							
Y19							
Y20							
Y21							
Y22						849	849
Y23							
Y24							
Y25							
Y26							
Y27							
Y28							
Y29							
Y30							
							1632

Table 66: Fund Source and Utilization

All debt is assumed to be serviced at an interest of 5% and the repayment periods are assumed to be over the next 5 years from the year of disbursement.

	Interest on Development Cost	Interest on Term Loan Stage 1	Repayment in 5 Years	Interest on Term Loan Stage 2	Repayment in 5 Years	Interest on Term Loan Stage 3	Repayment in 5 Years	Total Interest (D)	Total Repayment (E)
Y1	0							0	
Y2	37	0						37	0
Y3		40	80					40	40
Y4		32	80					32	113

Y5		24	80					24	105
Y6		16	80					16	97
Y7		8	80					8	88
Y8			0						80
Y9									
Y10									
Y11									
Y12				26				26	26
Y13				21	52			21	73
Y14				16	52			16	68
Y15				10	52			10	63
Y16				5	52			5	57
Y17				0	52				52
Y18									
Y19									
Y20									
Y21									
Y22						85		85	85
Y23						68	170	68	238
Y24						51	170	51	221
Y25						34	170	34	204
Y26						17	170	17	187
Y27						0	170		170
Y28									
Y29									
Y30									
								490	1965

Table 67: Interest on Borrowed Capital and Repayments

19. Cash Flow for Equity IRR & Annualized Rate of Return

With a DFBOT financing model and various assumptions, the FIRR, Equity IRR, and annualized returns considering an incrementally growing ridership and revenues for the concessionaire works out to 250%, 251%, and 19% respectively, without considering additional potential revenues from advertisements, property development, and in-vehicle infotainment.

		Total Revenue from Pass + Goods Trips +	Total A Cost of System Deployment	Total C Recurring Cost + 5% YOY	Total Repayment (E)	F Cash flow Operations and CAPEX (A-C)	G Admin, Sales & Mgmt.	H Operating Cash Flow (F - G)	I PBDT(H+A-C)	J Depreciation	K Profit Before Tax (I - J)	L Taxation	M Cash Flow after Interest, Capex, and Tax	N Cash flows for Debt	O Cash Flows after Debt Inflows and Outflows	Equity IRR	Annualized ROI
Pre-Operative	Y1		264			-264	0	-264		0	0	0	-264	0	-264		
	Y2		258		0	-258	0	-258		71	-108	0	-258	366	107		

Operations	Y3	225		134	40	90	2	88	48	56	-8	-3	50	-80	-30		
	Y4	246		141	113	105	2	103	71	45	25	8	63	-80	-17		
	Y5	269		147	105	122	3	119	95	37	58	17	78	-80	-3		
	Y6	295		154	97	140	3	137	121	30	91	27	94	-80	13		
	Y7	322		162	88	161	3	157	149	25	124	37	112	-80	32		
	Y8	353		169	80	183	4	180	180	21	159	48	132	0	132		
	Y9	386		177		209	4	205	205	18	187	56	149	0	149	6.5%	
	Y10	422		186		237	4	232	232	15	217	65	167	0	167	11.8%	
	Y11	462		195		268	5	263	263	13	250	75	188	0	188	15.4%	
	Y12	506	261	206	26	40	5	35	269	63	206	62	-53	261	207	17.9%	
	Y13	554		219	73	334	6	329	308	51	257	77	231	-52	179	19.4%	
	Y14	598		229	68	369	6	363	348	41	306	92	256	-52	204	20.6%	20%
	Y15	646		239	63	407	6	401	390	34	357	107	283	-52	231	21.6%	20%
	Y16	698		249	57	449	7	442	436	28	409	123	314	-52	262	22.4%	20%
	Y17	754		310	52	443	8	436	436	23	413	124	312	-52	260	23.0%	20%
	Y18	814		271		543	8	534	534	19	516	155	380	0	380	23.6%	20%
	Y19	879		283		596	9	587	587	15	572	171	416	0	416	24.1%	20%
	Y20	949		296		654	9	644	644	13	632	189	455	0	455	24.5%	20%
	Y21	1026		309		717	10	707	707	11	696	209	498	0	498	24.8%	20%
	Y22	1108	849	332	85	-74	11	-85	679	179	500	150	-320	849	529	25.1%	19%
	Y23	1196		393	238	803	12	791	724	143	580	174	549	-170	380	25.2%	19%
	Y24	1288		409	221	879	13	866	815	115	700	210	605	-170	435	25.4%	18%
	Y25	1388		426	204	961	14	947	913	93	821	246	667	-170	497	25.5%	18%
	Y26	1494		444	187	1050	15	1035	1018	74	944	283	735	-170	565	25.6%	18%
	Y27	1609		463	170	1146	16	1130	1130	60	1071	321	809	-170	639	25.7%	17%
	Y28	1733		482		1251	17	1234	1234	48	1185	356	878	0	878	25.7%	17%
	Y29	1867		503		1364	19	1345	1345	39	1306	392	953	0	953	25.8%	17%
	Y30	2010		524		1486	20	1466	1466	31	1435	430	1036	0	1036	25.9%	17%
		24096	1632	8053												25.9%	17.0%

Table 68: Equity IRR & Annualized Rate of Returns on Investment

I. Economic Appraisal

In this comparative analysis, all metrics have been borrowed from the DMRC DPR, since the system caters to the same number of users in the system and the location context remains the same.

The total financial cost is the aggregate of construction cost (capital cost) and recurring cost. Construction cost (capital cost) is derived after considering the cost of all major components such as Relocation and Rehabilitation (RR), civil construction for guideway, stations, depots, charging stations, rolling stock (Pod), manpower, etc. Recurring cost includes energy cost, maintenance cost, and operation cost. These costs are inclusive of central tax and yearly escalation costs applied to fixed costs.

1. Stream of Economic Benefit Value

Component-wise Stream of Economic Benefit Value at Economic Rates has been adopted from the DMRC DPR as tabulated below.

	Annual Travel Time Cost Save by PRT Passenger in Cr. Rs.	Annual Vehicle Operating Cost Save by PRT Passengers in Cr. Rs.	Annual Fuel Cost Save by PRT Passengers in Cr. Rs.	Annual Emission Cost Saving in Cr. Rs.	Annual Accident Cost Saving in Cr. Rs.	Annual Travel Time Cost Save by Road Passenger in Cr. Rs.	Annual Fuel Cost Save by Road Passengers in Cr. Rs.	Annual Infrastructure Cost Saving in Cr. Rs.	Total Benefits in Cr.
Y1									
Y2									
Y3									
Y4	89.6	21.1	20.7	3.2	3.1	12.4	1.2	3.5	155
Y5	100.3	23.1	21.8	3.5	3.4	13.3	1.2	3.9	171
Y6	112.3	25.3	23	3.8	3.6	14.4	1.2	4.2	188
Y7	125.8	27.6	24.3	4.1	3.9	15.5	1.3	4.6	207
Y8	140.9	30.2	25.6	4.5	4.2	16.8	1.3	5	229
Y9	157.7	33	27	4.9	4.5	18.1	1.3	5.5	252
Y10	176.6	36	28.5	5.3	4.8	19.5	1.4	6	278
Y11	197.4	38.9	29.7	5.7	5.1	21	1.4	6.5	306
Y12	220.6	41.9	31	6.2	5.5	22.6	1.5	7.1	336
Y13	246.5	45.3	32.3	6.7	5.9	24.3	1.5	7.6	370
Y14	275.5	48.9	33.7	7.3	6.2	26.2	1.5	8.3	408
Y15	307.9	52.8	35.1	7.9	6.7	28.2	1.6	8.9	449
Y16	344.1	57	36.6	8.6	7.1	30.3	1.6	9.7	495
Y17	384.5	61.5	38.1	9.3	7.6	32.6	1.7	10.5	546
Y18	429.8	66.4	39.7	10.1	8.1	35.1	1.7	11.3	602
Y19	480.3	71.7	41.4	10.9	8.6	37.7	1.8	12.2	665
Y20	536.8	78.5	43.2	11.9	9.2	40.6	1.8	13.2	735
Y21	590.1	84.5	44.9	12.8	9.8	43.4	1.9	14.3	802
Y22	648.7	90.9	46.6	13.9	10.5	46.5	1.9	15.4	874
Y23	713.1	97.7	48.5	15	11.2	49.8	2	16.6	954
Y24	783.9	105.1	50.4	16.2	12	53.3	2.1	17.9	1041

Y25	861.8	113.1	52.4	17.5	12.8	57.1	2.1	19.3	1136
Y26	947.4	121.6	54.5	19	13.7	61.1	2.2	20.9	1240
Y27	1041.5	130.8	56.6	20.5	14.6	65.4	2.3	22.5	1354
Y28	1144.9	140.7	58.9	22.2	15.6	70	2.4	24.3	1479
Y29	1258.6	151.4	61.2	24	16.6	74.9	2.4	26.2	1615
Y30	1383.6	162.2	63.6	26	17.8	80.2	2.5	28.3	1764
									18651

Table 69: Component-wise Stream of Economic Benefit Value at Economic Rates as per DMRC

2. Economic Cost of CAPEX & OPEX | IRR & NPV

To derive the economic costs of construction of the system taxes and escalation factors have been discounted and a factor of 86.18% has been applied to the same. All recurring costs have similarly been reduced by the same factor of 86.18% (as per DMRC DPR)

	Total Benefits in Cr.	Financial Cost - Capital Costs	Financial Cost - Recurring Costs	Economic Cost - Capital Cost	Economic Cost - Recurring Cost	Total Economic Costs	Total Economic Benefits	Economic IRR	NPV
Y1		264	0	228	0	228	-228		-203
Y2		258	0	223	0	223	-223		-381
Y3		0	134	0	116	116	-116		-463
Y4	155	0	141	0	121	121	34		-442
Y5	171	0	147	0	127	127	43		-417
Y6	188	0	154	0	133	133	55	-35%	-389
Y7	207	0	162	0	139	139	68	-23%	-359
Y8	229	0	169	0	146	146	83	-14%	-325
Y9	252	0	177	0	153	153	99	-7%	-290
Y10	278	0	186	0	160	160	118	-2%	-252
Y11	306	0	195	0	168	168	138	2%	-212
Y12	336	261	206	225	177	402	-65	0%	-229
Y13	370	0	219	0	189	189	181	4%	-187
Y14	408	0	229	0	197	197	210	7%	-144
Y15	449	0	239	0	206	206	243	9%	-100
Y16	495	0	249	0	215	215	280	10%	-54
Y17	546	0	310	0	267	267	278	12%	-13
Y18	602	0	271	0	234	234	368	13%	35
Y19	665	0	283	0	244	244	421	14%	83
Y20	735	0	296	0	255	255	480	15%	133
Y21	802	0	309	0	266	266	536	15%	183
Y22	874	849	332	732	286	1018	-144	15%	171
Y23	954	0	393	0	339	339	615	16%	216
Y24	1041	0	409	0	353	353	688	16%	262
Y25	1136	0	426	0	367	367	769	16%	307
Y26	1240	0	444	0	383	383	857	17%	352

Y27	1354	0	463	0	399	399	955	17%	397
Y28	1479	0	482	0	416	416	1063	17%	441
Y29	1615	0	503	0	433	433	1182	18%	485
Y30	1764	0	524	0	452	452	1313	18%	529
	18651	1632	8053	1406	6940	8347	10304	18%	529

Table 70: Economic Cost and Benefits | EIRR & NPV Y30

3. Summary of Economic Indicators

After generating the cost and benefit stream table, values of economic indicators are derived and are given below.

The project period is 2022 to 2052. Based on economic cost, EIRR is 17.82%, B/C Ratio is 1.81 and NPV is Rs. 529 Cr.

As per the ADB Guidelines, a single-option project is considered viable when either the ENPV is positive or the EIRR is greater than the minimum required discount rate. For the present study, ENPV is positive (Rs. 529 Cr.) and EIRR is 17.82% vis-à-vis the minimum required discount rate of 10%, which shows that the project is economically viable.

Economic Indicators	Economic Price
Cumulative Cost (Cr. Rs.)	10,304
Cumulative Benefit (Cr. Rs.)	18,651
Benefit-Cost (B/C) Ratio	1.81
NPV (Cr. Rs.)	529
EIRR	17.82%

Table 71: Economic Indicators for AutoBots for Haridwar Y 30

J. Summary Comparisons | DMRC DPR Vs AutoBots

4. Project Costs as per DMRC DPR & for AutoBots

	Item	Unit	Rate	Qty.	Amount (INR Cr.)
				Without taxes	
1.0	Land				90.86
2.0	Civil & Structure Cost	km	19.42	20.740	402.81
3.0	MEP cost	km	5.65	20.740	117.27
4.0	Charging Station Cost	No.	0.16	32.00	4.98
5.0	Depot	Each	LS	1	55.00
6.0	Control System	Each	LS	1	270.97
7.0	Total POD cost	no.	0.42	514.000	213.31
8.0	Total of all items except Land				1064.34
9.0	GC@5%				53.22
10.0	Contingencies@3%				31.93
11.0	Total cost of all items including General Charges, and Contingency without land				1149.49

AutoBots system by way of its light-weighted character does not require high CAPEX to start with. Key ingredients for making it lightweight vis-à-vis system proposed by DMRC DPR are

- Lower cost vehicles (by a factor of ~2 aggregate, by a factor of ~4 for each vehicle)
- Lower number of Pods (by a factor of ~3) to start operations without affecting supply given pods added incrementally to fleet from internal accruals/loan
- Structural system cost including MEP (by a factor of ~2)
- Control system cost (by a factor of ~3)
- No charging station costs
- Low cost of land required for Depot (by a factor of ~2)

	Cost of System Development	Units	Rate	Number	Total Cost (INR Cr)
	Company Affairs, Legal & System Sizing				0.90
	Planning Feasibility, Design & Detailing				5.00
1.0	Land Related	Sqm	20000	2785	5.57
2.0	Civil & Structure	Km	13.63	20	272.60
3.0	Depot	Each	1	LS	38.23
4.0	Control System	Each	1	LS	10.00
5.0	Total Pod Cost	No	0.1	1000	100.00
6.0	Total Cost without Land				427
7.0	General Costs @ 5%				21.3
8.0	Contingencies @3%				12.8
9.0	Total cost of all items including R&R, General Charges, and Contingency with land				466.44

Table 72: CAPEX Comparison between DMRC DPR proposed system & AutoBots system

5. DFBOT Model for Finance as per DMRC DPR & for AutoBots

As a result of a lower CAPEX requirement AutoBots at 60% of the cost of DMRC DPR suggested system, as an alternative system technology. A deployment consideration using the AutoBots technology is potentially very competitive in the marketplace.

A comparative picture of the Financing model is as follows

Sources of Funds | DMRC DPR	Amount (Rs/Crore)	% Of contribution
Equity by Concessionaire	451	30%
Market Borrowings by Concessionaire	1051	70%
Sub-Total (A)	1502	100%
Land Cost to be borne by Govt of Uttarakhand	91	
Sub-Total (B)	1593	
IDC on Loan (to be borne by the concessionaire)	182	
Total Cost including IDC	1775	
Sources of Funds | AutoBots	Amount (Rs Crore)	% Of contribution
Equity by Concessionaire	157	30%
Market Borrowings by Concessionaire	366	70%
Sub-Total (A)	522	100%
Land Cost to be borne Government Agency	0	
Sub-Total (B)	522	
IDC on Loan (to be borne by the Concessionaire)	37	
Total Cost including IDC	559	

Table 73: DFBOT Model Comparison between proposed DMRC DPR system & AutoBots system

In a system-wide context, the following features make any system more or less expensive to deploy. Typically, AutoBots features impact the first 4 items of the following list, resulting in a CAPEX of almost 1/3 the alternative as suggested by DMRC DPR.

- System size
- Peak system loading, average journey length, and desired average passenger wait time;
- Average vehicle occupancy during peak, and totality of flow (# empty vehicle movements);
- Amount of single versus bi-directional guideway;

Other Factors that may affect Cost, are not considered in this comparative analysis

- Station Density - stations required per guideway km;
- Amount of elevated/at-grade/tunnel/culvert/cantilever guideway;
- Proportion of standardized components (e.g., guideway curve sections)
- Deployment context (urban/public areas or semi-open/closed, controlled access such as airports & private campus areas), and associated security requirements;
- Integration with other site facilities/roads/pedestrian areas etc.;
- Customer's aspirations for station design;
- Customer requirements for custom vehicle appearances and characteristics

6. FIRR & Equity IRR quoted as per DMRC DPR

DMRC DPR analysis suggests a **FIRR of 16.85%** without any Property Development Income with the following sensitivities concerning variations in CAPEX, Revenues, and O&M costs.

It is important to note that the inherent anomalies in the computation of the quantum of alighting and boarding bays in each station by a factor of 2, suggest a poorer FIRR than what DMRC reported in their final report. The size and therefore cost of the stations will become 2X the size of that as proposed to make good the error.

Capital Cost			
20% increase in capital cost	10% increase in capital cost	10% decrease in capital cost	20% decrease in capital cost
14.93%	15.83%	18.05%	19.46%
Revenues			
20% decrease in Fare Box revenue	10% decrease in Fare Box revenue	10% increase in Fare Box revenue	20% increase in Fare Box revenue
12.77%	14.93%	18.62%	20.27%
O&M Costs			
10% increase in O&M cost		10% decrease in O&M cost	
16.14%		17.54%	

Table 74: FIRR and Sensitivity Analysis | DMRC DPR

Equity IRR as quoted by DMRC DPR works out to **EIRR 21.57%.** This computation, however, does not take into consideration the effect of *depreciation and income tax* on the cash flows.

7. FIRR and Equity IRR for AutoBots System at Haridwar

For AutoBots as an alternate System, the analysis suggests a **FIRR of 26.9%** without any Property Development Income with the following sensitivities concerning variations in CAPEX, Revenues, and O&M costs.

Capital Cost			
20% increase in capital cost	10% increase in capital cost	10Capital Cost	20% decrease in capital cost
23.88%	25.34%	28.99%	31.35%
Revenues			
20% decrease in Fare Box revenue	10% decrease in Fare Box revenue	10% increase in Fare Box revenue	20% increase in Fare Box revenue
20.06%	23.62%	30.32%	33.54%
O&M Costs			
10% increase in O&M cost		10% decrease in O&M cost	
26.22%		27.83%	

Table 75: FIRR and Sensitivity Analysis | AutoBots

Equity IRR for the same project with AutoBots technology works out to **EIRR 24.6%** considering the effect of *depreciation and taxation on income* in the cash flows.

In comparison, the Equity IRR without considering the effect of ***depreciation and taxes on income*** in the cash flows, like the method followed by DMRC DPR. works out to **EIRR 30.5%.**

8. Economic Returns Comparison

DMRC DPR computations for economic benefits work out as follows in comparison with AutoBots as an alternative technology system. Both systems are economically viable with positive NPVs and IRR of more than 10% as a minimum.

Economic Indicators	Economic Price DMRC DPR	Economic Price AutoBots
Cumulative Cost (Cr. Rs.)	10,876	10,304
Cumulative Benefit (Cr. Rs.)	18,651	18,651
Benefit-Cost (B/C) Ratio	1.71	1.81
NPV (Cr. Rs.)	265	529
Economic IRR	11.71%	17.82%

Table 76: Economic Indicators for Haridwar as per DMRC DPR Vs AutoBots for Y 30

9. Conclusions

The comparative key metrics suggest that the AutoBots system, duly denominated by seat capacity as 2 and resulting lighter structural system and the inherent flexibility in track deployments, can be a very competitive alternative to 4-6 seat systems for consideration in project deployments like the Haridwar PRT system connector.

4-6 seat PRT systems in comparison, need to deploy a heavier infrastructure from Day 1 of operations resulting in a higher upfront CAPEX.

Although the computations suggest the proposed 4-6 seat systems to operate with 100% occupancy, such an eventuality is not possible. A maximum 60-75% occupancy may be expected requiring the need for a larger fleet than is assumed to service the demand as per DMRC DPR.

Notes