ATOM - AuTonomous On-demand Mobility

First-of-its-kind AI-led public transport for India

CONCEPT BY
OLA MOBILITY INSTITUTE

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Ola Mobility Institute (OMI) is a new-age policy research and social innovation think tank of Ola, focused on developing knowledge frameworks at the intersection of mobility innovation and public good. The institute concerns itself with public research on electric mobility, energy and mobility, urban mobility, accessibility and inclusion, and the future of work and platform economy. All research conducted at OMI is funded by ANI Technologies Pvt. Ltd. (the parent company of brand Ola).

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Messages

“The solution to decongesting cities lies in integrating public transportation with efficient first and last mile solutions. Artificial Intelligence based technologies such as ATOM are conceptualised to reduce costs of building mass public transportation projects and to enable digital multi-modal integration. Concepts such as ATOM should inspire the private sector to invest in high quality public transportation and potentially solve the problem of congestion and pollution in Indian cities. I congratulate the Ola Mobility Institute for bringing out this novel application of Artificial Intelligence for Public Transportation in India.”
- Dr. O.P. Agarwal, CEO, World Resources Institute (WRI) India

“India has the most vibrant mobility ecosystem in the world that offers an opportunity for investors to introduce futuristic public transportation concepts such as ATOM. While the expansion of metro rail and BRTS systems is a welcome move, new concepts and technologies customised for Indian market can address some of the historical challenges. ATOM aims to solve the critical problems of operational efficiency and high capital investments that have resulted in limited private sector investments in public transportation. Concepts such as ATOM will help create a robust public transportation network even in Tier II and Tier III cities, meeting the ever-increasing mobility demand due to urbanisation. Upgrading an existing BRTS system with ATOM could be a good starting point for ATOM in India.”
- Mr. Ved Mani Tiwari, Ex-CEO, Sterlite Power; COO, National Skill Development Corporation

“ATOM provides an opportunity to introduce new technologies in mobility such as Blockchain and Artificial Intelligence. ATOM has rightly been re-imagined as the future of public transportation in India, a future that would involve vehicles communicating with each other, with traffic infrastructure and with a host of other sensors that will become part of the smart city. Blockchain will ensure secure communications that are critical to realise the vision of ATOM. ATOM as a concept holds great promise to provide a clean, efficient and viable transportation solution and could hold the key to make public transportation future ready in India.”
- Sanshiro Fukao, Board Member, Mobility Open Blockchain Initiative (MOBI)

“It was my pleasure to review this report. ATOM is a promising public transport concept. I am sure with further research and successful pilots this system can make substantial impact in coming future in Indian cities.”
- Dr. Ashish Verma, Associate Professor, Indian Institute of Science (IISc)
Acknowledgements

Conceptualising ATOM was possible only because of the cutting-edge and impactful work carried out by mobility innovators the world over. We are first and foremost grateful to Bhavish Aggarwal and the Ola group for showing the way to challenge the status quo and placing innovation at the centre stage of mobility discourse.

Our warmest gratitude goes to the following experts who provided invaluable input and feedback while conceptualising ATOM:
- Dr. O. P. Agarwal, CEO, World Resources Institute (WRI) India
- Mr. Ved Mani Tiwari, Ex-CEO, Sterlite Power; COO, National Skill Development Corporation
- Sanshiro Fukao, Board Member, Mobility Open Blockchain Initiative (MOBI)
- Dr. Ashish Verma, Associate Professor, Indian Institute of Science (IISc)

This report would not be possible without the creative spirit and dedicated efforts of various teams at OMI. Thanks are also due to Yeshwanth Reddy, Jagriti Arora, Aishwarya Raman, and Anand Shah for conceptualising ATOM.

We would also like to extend our sincere gratitude and appreciation to stalwarts who are helping create a paradigm shift in mobility. These experts ranging from researchers and policy advocates to practitioners and policymakers, among others, are rightfully highlighting the importance of equity, safety, and sustainability of mobility innovations, instead of hailing the interventions merely as engineering feats. Our concept, ATOM, thus, builds on these principles of impact and innovation alike.
EXECUTIVE SUMMARY

“In a rapidly transforming mobility paradigm, India has inherent strengths and comparative advantages. Our starting point is fresh. We have little of the legacy of resource-blind mobility. We have fewer vehicles per capita than other major economies. Thus, we do not carry much of the baggage of other economies that were built on the back of private car ownership. This gives us the window of opportunity to create an all-new, seamless mobility ecosystem.”

Hon’ble Prime Minister Narendra Modi’s Inaugural speech at the Global Move Summit 2018

India is witnessing a widespread transformation of mobility - redefining the way we work, move, and live - via the three revolutions of shared, connected and electric. NITI Aayog’s report, ‘Transforming India’s Mobility’ identifies 3C’s - ‘Clean, Convenient, and Congestion-free’ - for bringing about a paradigm shift in the way India travels. While the current focus on transforming mobility is hinged on going electric, it is imperative to simultaneously evaluate various emerging technologies to comprehensively solve mobility for a billion people.

This is particularly important in this age of urbanisation, where the United Nations has predicted these trends for India:

1. Urban population is set to grow from 410 million in 2014 to 814 million in 2050;
2. Urban agglomerations with a population of over 1 million will grow from 61 in 2018 to 71, with the addition of 4 new megacities by 2030;
3. Cities with a population of over 0.3 million will increase from 181 in 2018 to 235 in 2030.

Rising population means growing travel demand that needs to be met sustainably.

At 23 cars per 1000 people, India has the lowest per capita vehicle ownership compared to major economies, driving Indians to rely on shared mobility, such as buses, metro rail, taxi-cabs, auto-rickshaws etc. While the dependence on shared mobility is high, India does not have sufficient public transit to cater to its vast population. At 1.2 buses per 1000 people - a problem compounded by a vast disparity between states - India has the lowest per capita public bus availability. Recognising this lacuna, cities are actively strengthening public transport. They are adopting mass transit solutions - metro, tram, Bus Rapid Transit System (BRTS), monorail - that have been successful globally with the aim to provide safe, reliable, convenient and affordable services to all. However, metro and monorail are capital-intensive and time-consuming to build, and their financial viability remains a question. Given the diverse mobility needs of every city, a one-size-fits-all solution may not help transform mobility.

With the Artificial Intelligence (AI) revolution often hailed as the 5th Industrial Revolution brewing round the corner, can a disruptive idea change the public transport paradigm?

Can a new mass public transport system be built on new technologies? Can new technologies provide safe, equitable, viable, affordable, sustainable, efficient, and demand-responsive transportation?

The Ola Mobility Institute presents a first-of-its-kind AI-led public transport solution imagined for India and the world called ATOM - ‘AuTonomous On-demand Mobility’.

ATOM is an Artificial Intelligence based Public Transportation concept to provide a demand-responsive service in cities through access controlled roads. ATOM is a concept at the intersection of Shared, Connected, Electric, and AI-powered mobility presented as an alternative to metro rail and Bus Rapid Transit System (BRTS) to provide equitable, viable, clean, efficient, and demand-responsive public transportation for cities.
ATOM: AuTonomous On-demand Mobility

ATOM Explained

NIO (Native Intelligent Operative)
Passenger transport vehicles called NIOs are bus-like vehicles that run on lithium-ion batteries and are fitted with various components to enable a driverless and synchronised operation.

VARIANT 1: H-ATOM
This variant of ATOM has the highest passenger capacity catering to high traffic corridors with a maximum Peak Hour Peak Direction Traffic (PHPDT) of 40,000. NIOs move on a guideway, which is an elevated viaduct to enable higher average speed, less disruptions due to regular traffic and operation of higher capacity vehicles. This guideway will not require any additional land acquisition.

VARIANT 2: M-ATOM
This variant of ATOM has medium passenger capacity with a maximum PHPDT of 16,400. NIOs move on an at-grade access-controlled guideway at the centre of road with flyovers or underpasses at traffic intersections, thus enabling a higher throughput of passengers and avoid any interface with regular traffic.

VARIANT 3: L-ATOM
This variant of ATOM has low passenger capacity with a maximum PHPDT of 12,500. The L-ATOM guideway is an access-controlled at-grade roadway that’s capable of interacting with regular traffic at intersections. The traffic signals should have the facility to communicate with NIOs through V2I (Vehicle to Infrastructure) communication protocols.
Chain Configuration

The major differentiating factor for ATOM, compared to other high capacity public transit modes, is virtual platooning. This enables NIOs to operate in various configurations and sizes, dynamically to optimise occupancy and improve operational efficiency. NIOs can operate in configurations of 1 or 2 or 3 depending on the demand.
The ATOM transportation mode presented in this report offers savings on capital costs, reduces construction time, provides higher capacity utilisation, is demand responsive and has better operational efficiency compared to both Metro and Light Metro proposed for cities. Additionally, ATOM offers benefits over existing BRTS in terms of operational efficiency, demand-responsiveness and seamless commuting.

ATOM also offers a unique opportunity for India by providing a fillip to the government’s effort to improve public transportation. It provides an opportunity to revive private sector investments in public transportation. ATOM can also potentially help India match global technological developments in AI-based mobility, while addressing concerns being raised about driverless vehicle technology. It does this by virtue of operating in a controlled environment and being restricted to public transportation alone, similar to driverless metro trains already in operation.

ATOM is presented as an open source concept to stoke the imagination of various stakeholders, including private sector operators, OEMs, technology companies, manufacturers of various auto-components, universities, government agencies, and commuters. Inspired by the successful model of Public Private Partnerships in airports, it is recommended that the infrastructure for ATOM be provided as a service by the government. This would allow the private sector to manage operations and maintenance, while paying a user fee to the government for infrastructure. ATOM can be effectively implemented to provide public transportation in:

- Cities like Agra, Lucknow, Kanpur, Surat, Indore, Bhopal, Nashik, Visakhapatnam, Coimbatore, and Chandigarh where metro is currently being planned or under consideration, and the traffic projection for 30 years is under 40,000 PHPDF.

- Cities like Delhi, Bengaluru, Kolkata, Hyderabad, Chennai, Mumbai, Pune, Nagpur with existing metro rail networks, as a feeder or complimentary service on low traffic routes.

Feasibility studies can be undertaken for each of these cities by potential investors in ATOM. The following table estimates the costs of H-ATOM against Metro projects, which are either being implemented or in planning phase:

<table>
<thead>
<tr>
<th>City</th>
<th>Length of Metro in Km</th>
<th>Cost of Metro in Rs. Crores</th>
<th>Estimated Cost of ATOM in Rs. Crores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surat²</td>
<td>33</td>
<td>6,999</td>
<td>2,640</td>
</tr>
<tr>
<td>Gorakhpur¹</td>
<td>27.41</td>
<td>4,800</td>
<td>2,192</td>
</tr>
<tr>
<td>Visakhapatnam⁵</td>
<td>42.5</td>
<td>8,300</td>
<td>3,400</td>
</tr>
</tbody>
</table>

Note: Cost Comparisons only for Elevated portion of Metro

ATOM offers benefits to every stakeholder in the mobility ecosystem:

- **Government**
  - Significant reduction (> 50%) in capital investment, compared to metro
  - Promotes PPP in Public Transportation
  - Lower construction time compared to metro (> 50%)
  - Zero operational expenditure and investment
  - High service levels, improving commuter experience

- **Private Sector**
  - Large market potential and opportunity: 60+ cities in India alone
  - Viable investment option
  - Increased global competitiveness with futuristic technologies
  - Opportunities beyond public transportation

- **Commuters**
  - Affordable public transportation
  - Real-time information
  - Predictive journey time
  - Demand-responsive service ensuring high service quality
  - Digitally integrated transportation system

ATOM requires the integration of elements, such as rolling stock, AI, electric vehicle technology, civil construction, and high-value components like sensors/radars/actuators to enable autonomous driving. Transforming this concept into reality would require coordination among various stakeholders, who are specialised in individual components of the technology or as system integrators to put the building blocks of ATOM together.

ATOM’s promise lies beyond public transportation. Indeed, ATOM has the potential to revolutionise freight transport on access-controlled highways, intra-terminal transportation, and passenger transportation in large commercial and residential spaces. It can unlock higher investor value by opening up an all-new market for AI-based mobility in India.
Chapter 1

Public Transport Today

Mounting urban population and rising per capita income will lead to an exponential growth in demand for mobility. Cities need to meet this demand sustainably through public transportation and other shared mobility modes to ensure ease of moving and living. Right now, the mainstream public transport demands are changing.

Various urban public transportation modes operational today include rail-based (metro rail, monorail, trams), road-based (bus, BRTS), water-based (ferry) and air-based (helicopter). Most of these modes have existed for over 150 years; the first metro rail was made operational in 1863 in London. Typically, urban mobility requirements of various cities are evaluated to select a suitable mode from these existing options; with variations in carrying capacity, passenger traffic, and city-specific adaptations. Technologies for rolling stock, construction techniques, material, signaling systems, and source of energy for current rail, water, air, and road-based modes have evolved over the years. They have helped increase the speed of travel, improve safety, reduce the cost of transportation, cut construction time, help automation and more. Moving into the future, the revolution occurring through shared, connected, electric and AI-powered mobility would redefine the urban mass transit landscape.

New modes, such as Hyperloop are being developed to significantly reduce the travel time between cities compared to any existing mode of transport, including air travel. But the use of hyperloop for short distance intra-city transport is yet to be seen.

Indian cities have adopted modes of public transportation based on travel demand, size and population. The cost of transportation, cut construction time, help automation and more. Moving into the future, the revolution occurring through shared, connected, electric and AI-powered mobility would redefine the urban mass transit landscape.

1.1 Mass Public Transportation in India

State-run public bus services are the mainstay of public transportation in Indian cities. They provide low-cost mobility to masses through subsidies offered by the Government. As per the last report published by the Ministry of Road Transport and Highways in 2017, there are 54 State Road Transport Undertakings (SRTUs) in India, comprising services operated by state governments and a few municipal corporations.

Out of 1.75 million buses:

1. Private sector owns close to 1.61 million buses
2. Public sector owns 0.143 million buses
3. Public sector fleet size has remained constant for the past decade
4. Size of the bus fleet in India is suboptimal compared to the country’s population and travel demands

<table>
<thead>
<tr>
<th>Public Transit Systems Length in Km</th>
<th>Metro - Operational</th>
<th>Metro - Approved/ Under Construction</th>
<th>BRTS - Operational</th>
<th>Monorail</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>702</td>
<td></td>
<td>448</td>
<td>20</td>
</tr>
<tr>
<td>Thailand</td>
<td>1636</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Africa</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Russia</td>
<td>6.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1 - Bus availability

Figure 2 - Overview of length of Metro, BRTS, and Monorail

Rise of the Metro

With rapid urbanisation and an ever-increasing demand for providing sustainable urban public transportation, metro is now the preferred investment for mass transit in Tier 1 and Tier 2 cities. India has over 700 km of operational metro lines in 18 cities, and over 1,600 km of metro lines under construction in 27 cities.
intra-city bus services face the issues of mismatch in travel distance versus time taken, fleet utilisation,

Notwithstanding the challenges outlined in Page 21, public transit in the form of Metro rail or Monorail, and

Following are the major issues with adoption and implementation of world-class public transportation.

Adoption of public transportation and shifting people away from personal vehicles remains a challenge.

Way (RoW) needed on city roads.

Alternatives to the metro. Some have operational BRTS, but the coverage is limited due to exclusive Right of

Cities also have at-grade Bus Rapid Transit System (BRTS), Light Rail Transit System (LRTS) and monorail as

The most suitable mass transit option for a city is decided based on population, projected ridership or Peak Hour Peak Direction Traffic (PHPDT) and average trip lengths. The working group of transport for the 12th five-year plan (2012 - 2017) suggested the following criteria for mode selection:

<table>
<thead>
<tr>
<th>Mode choices</th>
<th>PHPDT (2021)</th>
<th>Population (2011 Census: in millions)</th>
<th>Average Motorised Trip Length (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metro Rail</td>
<td>&gt;= 10,000 for at least 5 km continuous length</td>
<td>&gt;= 2</td>
<td>&gt; 7-8</td>
</tr>
<tr>
<td>LRTS (Primarily at grade)</td>
<td>&gt;= 10,000</td>
<td>&gt;= 1</td>
<td>&gt; 7-8</td>
</tr>
<tr>
<td>Monorail</td>
<td>&gt;= 10,000</td>
<td>&gt;= 2</td>
<td>About 5-6</td>
</tr>
<tr>
<td>Bus Rapid Transit System</td>
<td>&lt;= 4,000 and up to 20,000</td>
<td>&gt;= 1</td>
<td>&gt; 5</td>
</tr>
<tr>
<td>Organised City Bus Service</td>
<td>&lt;= 50,000 (Hilly towns – 50,000)</td>
<td>&gt;= 1</td>
<td>2-3</td>
</tr>
</tbody>
</table>

Now, while with increasing congestion in cities, the demand for public transportation is rising, increasing adoption of public transportation and shifting people away from personal vehicles remains a challenge. Following are the major issues with adoption and implementation of world-class public transportation.

Notwithstanding the challenges outlined in Page 21, public transit in the form of Metro rail or Monorail, and intra-city bus services face the issues of mismatch in travel distance versus time taken, fleet utilisation, systemic inefficiencies, among others.

i. Capacity Utilisation

The accuracy of traffic demand projection, often significantly, determines the financial viability of mass transit projects.

A study12 carried out in 14 nations, both developed and developing, covering 210 transportation projects, revealed inaccurate traffic demand forecasting with a very high statistical significance.

- Kolkata Metro, for example, had a ridership of less than 10% of projected ridership in 2000. The actual ridership of 30 metro rail projects in USA was 65% lower than projected.
- For Kochi Metro, the ridership data16 released in June 2019 pegs the number at 40,000 per day against a projected ridership of 270,000 passengers even after 2 years of operations.

Ridership also varies significantly between peak and non-peak hours, reducing the occupancy ratio.

Delhi Metro currently has an average ridership of over 3 million per day. According to officials, most traffic is during peak hours from 8 am to 12 noon and 5 pm to 9 pm. Even during peak hours, the demand is not uniform and varies by routes. In fact, the discounted pricing of Delhi metro during non-peak hours indicates an under-utilised capacity.

ii. High Capex

Metro rail projects are capital-intensive. The operator has to bear the entire cost of civil infrastructure, rolling stock, and operations and maintenance. Road-based transport operators, on the other hand, only bear the cost of rolling stock, operations and maintenance of vehicles.

As a result, the cost of metro construction is around Rs 550-600 crore/km17 for underground metro and Rs 250-300 crore/km for the elevated corridor. These projects are financed through a mix of funding from the Central Government, State Government and debt.

The debt-servicing capability of the projects depends on reaching projected ridership, making these projects unviable for private sector, due to lower than projected ridership for most projects.

iii. High Construction Time and Delays

Delayed/extended construction time adds to the ‘opportunity cost’ associated with metro projects. The normal construction time for metro projects is five years. However, problems arising out of land acquisition, financing, rehabilitation and externalities associated with project management lead to delays in construction.

Hyderabad Metro, for example, was initiated in 2010 with a deadline of 2017 for completion of all the three phases. Currently, only two phases are operational due to delays in land acquisition, change of alignment, etc. and a large number of court litigations.

iv. High Cost of Travel

The average cost incurred by a metro rail is Rs 45-50 per trip and the average cost for road-based public transit is Rs 10-15 per trip. Rail-based mass transit is often more economical for long distances, greater than 10 kms. Road-based systems, on the other hand, tend to be more economical for shorter distances 3-5 kms. The same becomes comparable to rail-based systems for distances beyond 5 kms.

v. First Mile and Last Mile Connectivity

Cities face numerous challenges in developing an optimal network of public transportation, connecting residential and business districts. First and last-mile challenges to and fro metro stations too are nearly a universal concern. Integrating public transportation with affordable first and last mile solutions is key to driving its adoption.

B. BUS TRANSPORTATION

i. Low Service Levels

The fleet of public transport buses in India has remained constant over the last decade despite an exponential increase in demand and population. Factors impacting service levels are lack of standardisation in rolling stock, overcrowding during peak hours, frequency, coverage of bus routes, and lack of real-time information. Thus, public transportation is not the most preferred mode of commute due to low service levels.

ii. Low Capacity Utilisation

The Ministry of Road Transport and Highways published a report13 on the performance of State Road Transport Undertakings in India.
The average occupancy ratio in FY 2015-16 for 47 State Road Transport Undertakings (SRTUs) is 69.65%. The variations in occupancy between peak hours and non-peak hours is significantly high, thereby leading to low operational efficiency due to fixed costs, such as fuel and overheads.

iii. Poor Financial Health of SRTUs
Public bus services are currently financially unviable in India. The combined loss of SRTUs for financial year 2015-16 was Rs 11.369 crores. 40 out of 47 SRTUs have incurred losses, wherein only 7 have reported profits. Inter-city operations are profitable as compared to intra-city operations and compensate for losses to a certain extent.

1.2. Spotting Opportunities

India is projected to grow to a USD 5 trillion economy by 2024 and the contribution of cities to the national GDP is expected to exceed 70% by 2030. The United Nations projects that:

- urban population in India may grow from 410 million in 2014 to 814 million in 2050
- urban agglomerations with the population of over 1 million are expected to grow from 61 in 2018 to 71, with the addition of 4 new megacities by 2030
- cities with a population of over 0.3 million will grow from 181 in 2018 to 235 in 2030

Competitiveness of cities depends on factors, such as availability of human capital, physical infrastructure, ease of doing business, social and cultural character, global appeal, financial maturity and environmental factors. At the same time, rising congestion and pollution across cities that is not only affecting the quality of life but also productivity at work is a major cause of concern for citizens and businesses alike. A statement by UITP says that 50% of the cost of congestion is borne by businesses.

A quality public transport infrastructure would unlock several benefits like:

- improved efficiency of mobility by reducing travel time, congestion and pollution - leading to improvement in productivity at work
- better access to jobs or more opportunities and quality human capital in cities due to high quality and well-connected public transport
- increased disposable income due to reducing travel costs; further driving economic growth as the spending power would increase
- increased property values, which in turn, can be capitalised through additional taxes and augment Government revenues
- reduced demand for infrastructure development, such as expansion of roads, construction of flyovers, enabling local Governments to spend on essentials like education, healthcare, cleanliness, sanitation etc.

Investments in public transportation provide benefits beyond mobility and lead to economic growth and value creation for cities.

As one of the fastest growing large economies in the world, India can lead the 5th Industrial Revolution, which is driven by technologies such as AI, robotics, IoT, autonomous vehicles, nanotechnology, to name a few. India can surpass other developed nations in impact-driven technological interventions in urban mobility.

AI Advantage

According to a report by NITI Aayog, AI has the potential to add USD 1 trillion to the Indian economy by 2035. It has been mandated to establish a ‘National Program on Artificial Intelligence’ to guide research and development in new and emerging technologies.
2.1 What is ATOM

ATOM is an Artificial Intelligence-based public transportation concept to provide a demand-responsive service in cities through access controlled roads. ATOM is a concept at the intersection of Shared, Connected, Electric, and AI-powered mobility presented as an alternative to metro rail and BRTS to provide equitable, viable, clean, efficient, and demand-responsive public transportation for cities. The vehicles called NIOs or Native Intelligent Operatives move in a defined virtual loop of GPS coordinates through a road-based guideway.

To cater to the different demands and requirements of cities, three variants of ATOM can be implemented based on traffic demand and viability:

- **H-ATOM**: An elevated guideway catering to high traffic corridors with a maximum PHPDT of 40,000.
- **M-ATOM**: An at-grade access-controlled guideway with flyovers or underpasses at traffic intersections, catering to medium traffic corridors with a maximum PHPDT of 16,400.
- **L-ATOM**: An at-grade access-controlled guideway with traffic signals at intersections/junctions, catering to low traffic corridors with a maximum PHPDT of 12,500.

ATOM is a unique solution that reimagines public transportation for India and the world. It has the potential to emerge as a widely successful and sustainable alternative.

2.2 Salient Features

ATOM is an integration of various components and technologies as follows.

2.2.1 Anatomy of a NIO (Native Intelligent Operative): Passenger transport vehicles called NIOs are bus-like vehicles, which run on lithium-ion batteries and are fitted with various components to enable a driverless and synchronised operation.

**Global Positioning System (GPS)**: The Global Positioning System accurately determines the position of the vehicle and transmits data to the on-board computer system to navigate effectively.

**Light Detecting and Ranging Sensors (LiDAR)**: The sensor creates a 3D map of the surrounding environment, employing 64 lasers that spin 900 rpm to give a 360-degree view to the drivers. LiDAR helps identify potential hazards, their distance and profile by bouncing light off the surroundings. LiDARs for ATOM can be optional depending on the safety standards as the operating environment is restricted.

**Radar Sensors**: Radar sensors reside on the back and front of the vehicle. Sensing the speed of its surrounding objects, they preempt possible collisions by signalling the vehicle to brake.

**Cameras**: These construct a picture of the surroundings to identify traffic lights, road signs, pedestrians, cyclists and other vehicles.

**Central Computer**: The on-board computing system processes signals from various sensors and controls the movement of the vehicle with support from the AI control platform onboard the vehicle computer.
INTELLIGENT MOVE

The AI platform makes decisions based on inputs from vehicle sensors, control room inputs and accordingly sends signals to the actuators such as steering, braking and power-train to ensure vehicle movement as per assigned routes, speeds and frequency.

**Inputs**

- Vehicle Sensors (LiDAR, Cameras, Radar + GPU + IMU)
- Route + Chain Control
- Passenger + Station Control
- Battery Management System

**Output**

- Onboard Computing System + AI Platform
- Actuators (Steering, Breaks, Powertrain)
- Vehicle Doors
- EV Charging Port

**Figure 7** - Control System Flow Diagram

**Figure 8** - Interaction between the control room and vehicles through V2N communication

**Infrared Sensors:** Detects heat signals from objects to identify obstacles using computer vision algorithms running on a dedicated image signal provider (ISP) and application specific integrated circuit (ASIC). Such sensors are capable of identifying thermal signatures of animals, signatures of cyclists and pedestrians, etc.

**Ultrasonic Sensors:** Used for determining range based on “time of flight”, these sensors emit a chirp and wait for a bounce back. In addition to determining distances, they are also capable of sensing dirt.

**Inertial Measurement Unit (IMU):** The IMU is used to improve the accuracy of navigation and provide localised data by combining data with other sensors on board the vehicle. IMU measures three linear acceleration components and three rotational rate components using accelerometer and gyroscope. IMU’s data is also used as a back-up in case of failure or errors in data of other sensors and navigate the vehicle for a short period of time.

**V2X Communication:** The V2X unit onboard the vehicle is based on WLAN 802.11p standards enabling communication between V2V (Vehicle to Vehicle), V2I (Vehicle to Infrastructure) and V2N (Vehicle to Network). The V2X unit uses Dedicated Short Range Communication (DSRC), which is a one-way or two-way short-to-medium-range wireless communications to talk to and inform each other about the surrounding environment.
Dimensions & Seating: The dimensions of a NIO can be customised based on traffic demand. The following images show different sizes of NIOs.

Battery/ Power Source: NIOs are operated as mass transit vehicles that may travel a distance of more than 500 kms per day. Therefore, the power source for NIO should withstand a large number of fast charging cycles (less than 8-10 mins each) and high fluctuation of power due to constant acceleration and deceleration. Lithium-ion batteries with a capacity to withstand the constant acceleration and deceleration along with higher charge cycles are required. Alternatively, higher capacity batteries can be used, which would increase the capital costs and cost of battery replacement at the end of battery life.

Battery Charging: An overhead battery charging unit is envisaged to enable automatic charging of vehicles at designated charging areas in the depot. The provision for charging NIOs would be made at the top, as shown in figure 6.

Actuators: Actuators perform the actions of braking, steering and acceleration based on signals received from the onboard computing system. The signals to actuators are based on the signals received from various sensors to drive in the defined route at a desired speed, including stopping at stations and signals, and upon detecting obstacles. An option of manual override with drivers in NIOs can be included to handle emergency situations or failure of systems.

2.2.2 Guideway

The guideway for ATOM transportation mode is a combination of road infrastructure/ elevated viaduct, access controlled infrastructure and a fixed virtual path, defined by geo-positioning coordinates (similar to flight paths). The guideway also includes infrastructure that enables V2I communications, such as road signs, markings, signals, warning symbols, parking bays etc. to enable navigation of the NIOs.
H-ATOM Guideway: The guideway is an elevated viaduct to cater to high traffic demands. An elevated guideway enables higher average speed, less disruptions due to regular traffic and operation of higher capacity vehicles. This guideway will not require any additional land acquisition. The design specifications are proposed to be similar to elevated metro rail viaducts, except the design loads would be lower due to the absence of superimposed dead load, such as plinth, cables, cable trays, electric poles, rails and signalling. For reducing cost and time, value engineering principles like modular construction, metal structures can be adopted.

M-ATOM Guideway: This guideway is an access-controlled at-grade roadway with flyovers or underpasses at traffic intersections to enable a higher throughput of passengers and avoid any interface with regular traffic. Building this guideway requires expansion of existing roads with potential requirement of land acquisition to increase the Right of Way. Recommended width of the M-ATOM guideway is 7.5 meters.

L-ATOM Guideway: The guideway is an access-controlled at-grade roadway that’s capable of interacting with regular traffic at intersections. Building this guideway requires expansion of existing roads with potential requirement of land acquisition to increase the Right of Way. Recommended width of the L-ATOM guideway is 7.5 meters. The traffic signals should have the facility to communicate with the NIOs through V2I protocols.

Virtual Path: The virtual path in ATOM is similar to a flight path for air travel. The path is fixed by pre-defining the GPS coordinates for movement of the NIOs. NIOs only move in these fixed routes, similar to moving on railway tracks.
2.2.4 Chain Configuration

The major differentiating factor for ATOM, compared to other high capacity public transit modes, is the virtual platooning, enabling NIOs to operate in various configurations dynamically to optimise occupancy and improve operational efficiency.

For example, three NIOs can operate together as a three-coach train during peak hours, as two-coach and single coach trains during non-peak hours based on demand. NIOs are attached virtually by locking-in their position with other NIOs in the chain. The first NIO in the direction of movement acts as the prime mover, and the inputs to other NIOs in the chain are synchronised with the prime mover.

For an integrated ATOM transportation across H-ATOM, M-ATOM and L-ATOM, virtual platooning allows NIOs to be operated across three modes to further improve efficiency while enabling integration like no other transportation mode. This configuration is enabled through the AI platform that can bundle the movement of multiple vehicles together.

2.2.5 Stations

The stations for H-ATOM would resemble metro rail stations with a single floor configuration, with reduced platform length and design load, thereby reducing costs of stations. Security will be provided through technology, such as CCTV to reduce operational costs. For at-grade stations, separate under passes or foot-over bridges or pedestrian crossing signals will be provided to enable easy access to stations.

For at-grade guideways, stations would be staggered to reduce the width of guideway at stations, thereby ensuring minimal reduction in road-width for regular traffic.

2.2.6 Depot

A depot would typically consist of an Operations and Control Centre, EV Charging Infrastructure and Vehicle Repair and Maintenance Centre. For cities with multiple variants of ATOM, a single Depot is proposed.

2.2.7 Ticketing

Mobile app-based ticketing systems would be implemented to ensure accuracy of demand responsiveness. The mobile application installed by passengers for ticketing, would provide accurate location details, which could feed into intelligent algorithms developed for demand management. A QR code generated through the mobile application can be used to enter and exit the stations. Mobile-based ticketing would be interoperable with other modes of transport in the city of operation, such as bus, app-based aggregator services etc. In addition to mobile app-based ticketing, smart card-based ticketing would also be available to serve commuters without smartphones.

2.3 AI Platform as Technology

A critical component of the ATOM transportation mode is the Central Control Centre, which houses the AI platform to control the complete operations.

There are two AI platforms – one in the vehicle to control its navigation and operations, and the other in the central control centre. The central control centre performs the following functions:

- Route allocation
- Demand estimation
- Supply management
- Vehicle charging management
- Grouping (Chaining) of vehicles
- Handling of emergency situations
- Over-riding autonomous driving

The AI platform could be proprietary or on Software-as-a-Service (SaaS), depending upon the availability of technology and mode of implementation.
2.4 Integration of ATOM Variants

The three types of ATOM can operate independently or be integrated with one another to provide a complete ATOM transportation mode across a city. Integration would enable a NIO on L-ATOM to operate in M-ATOM and H-ATOM modes or vice versa.

Let’s assume an ATOM public transportation grid for a city consisting of all three integrated modes of ATOM:

- NIOs or passenger vehicles are operated across all three modes, and can enter other modes at the interchange points indicated.

- NIOs are programmed to operate at different speeds, frequencies, and chain configurations in each mode.

- Configuration of NIOs is updated based on the mode of ATOM in which it is operated.

For example, a NIO operating in M-ATOM can enter H-ATOM mode and form a 3-coach chain configuration with existing 2-coach configuration in the H-ATOM.

In case of integrated ATOM modes for a complete city grid, based on complexity and transport demand across routes, two types of virtual paths can be defined:

Figure 17 - Integrated ATOM

**Figure 17** - Integrated ATOM

In case of integrated ATOM modes for a complete city grid, based on complexity and transport demand across routes, two types of virtual paths can be defined:

a. **Single Loop Path:** In this virtual path, there would be a single entry point and single exit point for every vehicle for the complete grid. Thus, a vehicle would operate across multiple modes, in various chain configurations in a single trip.

b. **Multiple Loop Path:** In this path, there would be multiple routes, multiple entry and exit points for every vehicle. A vehicle can operate across multiple modes, in various chain configurations. However, the entry and exit points for each type of ATOM will be separate.

**Figure 18** - Simple single loop across two modes

**Figure 19** - Simple multiple loop path for two modes

2.5 Choosing the Right ATOM

The selection of ATOM mode would be based on a) Peak Hour Peak Direction Traffic (PHPDT) of the project in the city where it would be implemented, b) availability of land, c) future expansion, and d) population growth.

A minimum headway of 1.5 minutes between vehicles or chain has been considered for calculations presented here for H-ATOM and M-ATOM, and 2 minutes for L-ATOM.
Table showing maximum PHPDT capacity of each ATOM mode:

<table>
<thead>
<tr>
<th>ATOM Mode</th>
<th>Chain Configuration</th>
<th>Minimum Headway</th>
<th>Maximum PHPDT</th>
<th>Right of way</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-ATOM</td>
<td>3</td>
<td>1.5 minutes</td>
<td>25,000</td>
<td>Nil</td>
</tr>
<tr>
<td>H-ATOM</td>
<td>4</td>
<td>1.6 minutes</td>
<td>30,000</td>
<td>Nil</td>
</tr>
<tr>
<td>H-ATOM</td>
<td>5</td>
<td>1.8 minutes</td>
<td>35,000</td>
<td>Nil</td>
</tr>
<tr>
<td>H-ATOM</td>
<td>6</td>
<td>1.8 minutes</td>
<td>40,000</td>
<td>Nil</td>
</tr>
<tr>
<td>M-ATOM</td>
<td>1</td>
<td>1.5 minutes</td>
<td>8,200</td>
<td>75 m</td>
</tr>
<tr>
<td>M-ATOM</td>
<td>2</td>
<td>1.5 minutes</td>
<td>16,400</td>
<td>75 m</td>
</tr>
<tr>
<td>L-ATOM</td>
<td>1</td>
<td>2.0 minutes</td>
<td>6,200</td>
<td>75 m</td>
</tr>
<tr>
<td>L-ATOM</td>
<td>2</td>
<td>2.0 minutes</td>
<td>12,500</td>
<td>75 m</td>
</tr>
</tbody>
</table>

**INTELLIGENT MOVE**

The difference between L-ATOM and M-ATOM emerges as the average speed of L-ATOM would be lower given the interaction with traffic at junctions. The cost-benefit analysis along with the impact of L-ATOM on traffic and congestion in the city needs to be considered for decision-making.

**Integrated ATOM:**

An integrated ATOM implementation can be considered for brownfield cities with a mix of high, medium, and low demand corridors, which provide an integrated public transportation mode.

- High demand corridors with PHPDT over 16,400 and up to 40,000 could be considered for H-ATOM.
- For PHPDT below 16,400, M-ATOM and L-ATOM selection depends on the availability of land, cost of land acquisition for brownfield cities. This is because the RoW would need to be expanded to provide land for M- and L-ATOM.

**Independent ATOM:**

For greenfield cities, L-ATOM would be an ideal choice given the low initial demand and lower cost of land acquisition. Master planning for greenfield cities could incorporate a dedicated RoW for ATOM at the planning stage. ATOM could then evolve into M-ATOM and H-ATOM based on demand growth.

Independent H-ATOM would be ideal for brownfield cities with projected traffic below 40,000 PHPDT over the 25 year life-cycle of the project, and can be implemented instead of elevated metrol or light metro projects. The benefits of H-ATOM over metro rail are elaborated later in the report.

Independent M-ATOM can be built in brownfield cities that have available RoW for expansion of the road and corridors with a maximum projected traffic of 16,400 PHPDT.

Independent M- and L-ATOM can be considered for brownfield cities with existing BRTS that can be upgraded to ATOM. Conversion of BRTS to ATOM would require upgrading the rolling stock and implementing other elements of ATOM like signals, signages, along with control centre and charging infrastructure.

Overall, ATOM can be implemented in brownfield or greenfield cities in various combinations. It can be deployed in an integrated fashion, where H-ATOM, M-ATOM, and L-ATOM are all integrated, catering to a mix of high, medium, and low demand across various corridors. Or ATOM can be deployed as stand-alone mass transit projects, i.e., independent ATOM. In either case, ATOM has to be well integrated with transport modes offering first- and last-mile connectivity. This will ensure adequate demand for and utilisation of ATOM.

**2.6 Implementing the ATOM**

Various operational models for public transportation exist in India, majority of which are operated by wholly-owned Government organisations for bus and metro rail-based services. Two models of ownership that exist are:

- **EPC (Engineering Procurement Construction)** – the most commonly implemented model for BRTS or metro projects. The ownership of design, construction, operations, and maintenance is with the government entity.
- **PPP (Public Private Partnership)** – such as Hyderabad Metro Rail which is executed under Design Build Finance Operate and Transfer model while Mumbai Metro One which operates Line 1 is jointly owned by the Government and a private player.

The PPP models in the bus services are more established in the form of Gross and Net Cost Contracts, where the government authority or transit agency outsources operations, maintenance, and even fare collection while retaining the planning and monitoring of services. These models reduce the risk for the government and improve the service efficiency as the private operator is compensated based on the kms operated.

Investments in transport and road infrastructure are now being mandated to be developed under PPP models.

**Summary of the roles of Government and private actors in this implementation model:**

<table>
<thead>
<tr>
<th>Description</th>
<th>Government</th>
<th>Private Player</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Acquisition, Rehabilitation &amp; Resettlement</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Design</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Build (Civil Infrastructure)</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Build (Technology and Rolling Stock Infrastructure)</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Operations</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Finance (Civil Infrastructure)</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Finance (Rolling Stock, Technology, Control Centre, Operational Costs etc)</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Security</td>
<td>✔</td>
<td></td>
</tr>
</tbody>
</table>

This model is similar to the infrastructure as a Service (IaaS) model of airports, where governments build the airports and the airlines pay for the usage of the infrastructure. To further reduce costs for the government, wherever viable, partial funding of the civil construction cost could be borne by the private player.
Any new meaningful public transportation solution needs to address issues, such as high capex costs, low capacity utilisation, high construction time, viability and affordability. In such a scenario, ATOM scores by virtue of its simple, yet transformative thinking, inherent features and breakthrough technologies that are tailored for India.

The three variants of ATOM provide an alternative to current public transportation modes of metro rail (elevated and at-grade), bus-rapid transit system and trams. Here, the benefits of ATOM over these modes are explored in detail with relevant case studies. To begin with, the table offers a summary of the benefits of each variant of ATOM.

### Economic Benefits

#### H-ATOM vs. Metro
- Lower capex per km
- Higher operational efficiency
- Lower construction time
- Viable for private sector investments
- Improved affordability in the long-term
- Digital integration with first and last mile solutions

#### M-ATOM & L-ATOM vs. BRTS & Light Rail
- Lower Capex per km w.r.t Light Rail
- Higher operational efficiency w.r.t BRTS and Light Rail
- Higher operational capacity w.r.t BRTS
- Digital integration with first and last mile solutions

### 3.1 H-ATOM vs. Metro

To elucidate this scenario, imagine building ATOM for the city of Alpha. Due to an exponential growth in mobility demand and future growth potential, the city is considering the development of a mass transit solution. The city is linear in nature, and a single corridor of 18.5 km is being considered for developing the mass transit system. The various mass transit options available to the city are BRTS, Monorail and Metro. Given the expected passenger traffic and future growth of the city, the city is considering Elevated Metro as a potential solution.

Accordingly, the city has commissioned a DPR study to finalise the alignment, and estimate the traffic, revenues, costs, designs, etc. for a metro project. The estimated capital costs from the DPR make it unviable for the city to fund the project. Given the low traffic projections, it is not viable for the private sector. PPP mode is not suitable to build the metro project either.

#### Need for a New Disruptive Solution

Currently, the city is evaluating new technology-based mobility solutions, reflecting the core culture of the city and to attract private investments for the project. The city administration has been introduced to the new concept developed by the Ola Mobility Institute called the ATOM.

ATOM uses AI-driven level-5 autonomous vehicles in controlled environments to provide mass transit systems with similar passenger capacity, as a light or medium metro. The city administration is keen to know more about the ATOM and its benefits over the Metro. The administration is specifically interested in financial and operational benefits of ATOM.

#### Project Requirements
- Length of Corridor: 18.5 km
- Number of Stations: 19
- Length of Elevated Corridor: 18.5 km
- Maximum Peak PHPD (2019): 7,746
- Maximum PHPD (2044): 11,882
- Ridership day (2019): 184,081
- Ridership day (2044): 286,031
- At Grade or Underground Corridor: None
- Operational Hours: 7 am to 11 pm
- Ticketing: Smart Ticketing/QR Code

#### Capex per km Calculations

To calculate the capex costs, the following pricing guidelines have been used:

- Prices for Metro have been derived from guidelines on pricing ‘Report on Benchmarking of Metro Rail Projects’ issued by the Ministry of Housing and Urban Affairs in February 2019.
- Civil cost for H-ATOM wherever applicable has been derived from pricing of metro, especially for elevated corridor, stations, and depot; these prices have been adjusted to reflect the projected cost for H-ATOM based on reduced design load, change of design, lower mechanical forces, etc.
- Conservative cost estimations have been used for H-ATOM, which would further be optimised with technology and value engineering.
- Civil cost for H-ATOM wherever applicable has been derived from pricing of metro, especially for elevated corridor, stations, and depot; these prices have been adjusted to reflect the projected cost for H-ATOM based on reduced design load, change of design, lower mechanical forces, etc.
- Conservative cost estimations have been used for H-ATOM, which would further be optimised with technology and value engineering.
Capex Cost Comparison: Metro vs H-ATOM

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Metro (INR crores)</th>
<th>H-ATOM (INR crores)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIVIL COST</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of Metro Stations</td>
<td>494</td>
<td>296</td>
</tr>
<tr>
<td>Cost of Elevated Corridor</td>
<td>687</td>
<td>616</td>
</tr>
<tr>
<td>Cost of Depot</td>
<td>105</td>
<td>59</td>
</tr>
<tr>
<td>Cost of Metro Rail Bhawan / OCC building</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>ELECTRICAL COSTS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metro Station EM Works</td>
<td>152</td>
<td>76</td>
</tr>
<tr>
<td>Metro Bhawan/OCC bldg EM Works</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Depot EM Works</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>OTHERS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of Rails (P-Way)</td>
<td>132</td>
<td>0</td>
</tr>
<tr>
<td>Traction &amp; Power Supply</td>
<td>412</td>
<td>0</td>
</tr>
<tr>
<td>Signalling and Telecom</td>
<td>359</td>
<td>0</td>
</tr>
<tr>
<td>Rolling Stock</td>
<td>288</td>
<td>74</td>
</tr>
<tr>
<td>Capital Expenditure on Security</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>EV Infrastructure</td>
<td>0</td>
<td>59</td>
</tr>
<tr>
<td>AV Technology Platform</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Blacktop Road</td>
<td>0</td>
<td>19</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>92</td>
<td>37</td>
</tr>
<tr>
<td>Contingencies</td>
<td>84</td>
<td>45</td>
</tr>
<tr>
<td>TOTAL IN INR CRORES</td>
<td>2,889</td>
<td>1,497</td>
</tr>
</tbody>
</table>

(OMI Analysis)

b. Project Viability:

Establishing the viability of any public transportation investment is critically dependent on the ridership, a major source of revenue. For metro projects operational across the globe, it has been observed that the actual ridership is often lesser than the ridership projected or estimated at the time of planning. This has hampered the ability of the private sector to invest in mass transit operations and maintenance.

The implementation model for ATOM delineates the roles of the government and private sector.

While the model recommends the governments to develop civil infrastructure, like the elevated corridor, stations and depot, the analysis also considers partial investments by the government in civil infrastructure to understand its impact on project viability.

Revenues considered for analysis are ticket revenues from commuters and advertisement revenues for implementation of ATOM in the city of Alpha.

This table analyses the sensitivity of the Government viability gap funding under the PPP mode and IRR scenarios for reduction in project traffic.

Internal Rate of Return Scenarios

<table>
<thead>
<tr>
<th>Civil Cost Government Funding in %</th>
<th>0%</th>
<th>20%</th>
<th>40%</th>
<th>60%</th>
<th>80%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government Funding in Crores (INR)</td>
<td>0.00</td>
<td>234.40</td>
<td>468.80</td>
<td>703.20</td>
<td>937.60</td>
<td>1172.00</td>
</tr>
<tr>
<td>IRR in %, 100% of Projected Traffic</td>
<td>16.33</td>
<td>18.6</td>
<td>21.73</td>
<td>26.48</td>
<td>35.25</td>
<td>63.14</td>
</tr>
<tr>
<td>IRR in %, 80% of Projected Traffic</td>
<td>12.65</td>
<td>14.58</td>
<td>17.19</td>
<td>21.04</td>
<td>27.88</td>
<td>47.75</td>
</tr>
<tr>
<td>IRR in %, 70% of Projected Traffic</td>
<td>10.51</td>
<td>12.26</td>
<td>14.6</td>
<td>18.02</td>
<td>23.92</td>
<td>40.07</td>
</tr>
<tr>
<td>IRR in %, 60% of Projected Traffic</td>
<td>8.01</td>
<td>9.59</td>
<td>11.66</td>
<td>14.64</td>
<td>19.62</td>
<td>32.29</td>
</tr>
</tbody>
</table>

(OMI Analysis)

Based on the financial health of the implementing Government, the amount of funding could be decided. The analysis projects a healthy return on investment, even if the traffic is lower than estimated. However, given the dynamic nature of ridership, a flexible implementation model - with investment by the government in civil infrastructure, and a payback schedule from the private operator for civil infrastructure - could be considered.

Operational and Maintenance Costs:

Operational costs include human resources, electricity, EV charging technology, and AV technology platform. Maintenance costs include battery replacement every 3 years, charging infrastructure maintenance, AV technology upgrades, rolling stock repairs, elevated corridor maintenance and miscellaneous expenses.

The Operations & Maintenance (O&M) costs for year 1 of operation for H-ATOM is INR 3.56 crores/km of operational length. For metro, the O&M costs for year 1 is INR 3.61 crores/km of operational length. The estimations for O&M costs of H-ATOM do not include the savings due to dynamic platooning.


3.2 M-ATOM and L-ATOM vs BRTS/ Light Rail (At-Grade)

a. Capex Requirements: The cost analysis of implementing M-ATOM and L-ATOM as at-grade mobility solutions against existing at-grade solutions, such as BRTS and Light Rail needs to be looked at. The report ‘Life Cycle Cost Analysis of Five Urban Transport Systems’ published by the Institute of Urban Transport (IUT) in collaboration with the Bangalore Metro Rail Corporation20 has been used as reference for capex of BRTS and Light Rail (at-grade). For cost comparison, the following assumptions have been used as specified in the IUT report:

- a route of 20 km
- 25 stations
- each at a distance of 750 meters

The complete route is at-grade. There is no elevated corridor, except for M-ATOM where flyovers are constructed at every traffic junction. 12 traffic junctions have been assumed, each with a length of 250 metres.

<table>
<thead>
<tr>
<th>Capex Cost Comparisons</th>
<th>BRTS (INR crores)</th>
<th>L-ATOM (INR crores)</th>
<th>M-ATOM (INR crores)</th>
<th>At-Grade Light Rail (INR crores)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>289</td>
<td>289</td>
<td>289</td>
<td>289</td>
</tr>
<tr>
<td>Road Way Development</td>
<td>171</td>
<td>171</td>
<td>171</td>
<td></td>
</tr>
<tr>
<td>Railway - Civil Infrastructure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Railway - Electrical</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bus Stops/ Stations</td>
<td>10.8</td>
<td>10.8</td>
<td>10.8</td>
<td></td>
</tr>
<tr>
<td>Bridges and Flyovers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depots</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>75.4</td>
</tr>
<tr>
<td>Workshop and Terminals</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Operation and Control Centre</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>ITS application</td>
<td>29.5</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Rolling Stock</td>
<td>148</td>
<td>112</td>
<td>112</td>
<td>1240</td>
</tr>
<tr>
<td>Signalling</td>
<td></td>
<td></td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>General Charges at 3%</td>
<td>22</td>
<td>23</td>
<td>26</td>
<td>23</td>
</tr>
<tr>
<td>Contingencies at 3%</td>
<td>23</td>
<td>24</td>
<td>27</td>
<td>24</td>
</tr>
<tr>
<td>TOTAL IN INR CRORES</td>
<td>794</td>
<td>831</td>
<td>932</td>
<td>2259</td>
</tr>
</tbody>
</table>

(OMI Analysis)

It is evident that ATOM offers a higher capacity compared to BRTS for similar Capex, and provides a similar capacity as light rail for 171% lower capex. Capacity for M-ATOM can be designed for up to 20,000 PHPDT with lesser headway and higher chain configuration.

b. Operational Capacity:

ATOM provides higher operational efficiency compared to BRTS as it can operate fleet at lower headway for vehicles with the same capacity due to the automation from AI platform, as well as ATOM can run chain configuration more effectively for a higher throughput. Compared to at-grade light-metro, ATOM can provide similar throughput. Additionally, the dynamic platooning during non-peak hours will ensure higher vehicle occupancy ratio compared to BRTS and light metro.

3.3 Seamless Integration of First and Last Mile Connectivity

While ATOM does not offer a solution to solve the first and last mile connectivity, which is a major roadblock for the adoption of public transportation in India, the predictive AI platform controlling the headway will introduce a new dimension of predictability of travel time for commuters. This can be made possible by integrating aggregator platforms with ATOM that provide an integrated trip planning, ticketing and payment experience.
ATOM is presented as an open-source concept to stoke the imagination of various stakeholders, including the private sector operators, OEMs, technology companies, manufacturers of various auto-components, universities, Governments and commuters. It can be effectively implemented to provide public transportation in:

- **Cities like Agra, Lucknow, Kanpur, Surat, Indore, Bhopal, Nashik, Visakhapatnam, Coimbatore, and Chandigarh** where metro is currently being planned or under consideration and the traffic projection for 30 years is under 40,000 PH2DP.
- **Cities like Delhi, Bengaluru, Kolkata, Ahmedabad, Kochi, Hyderabad, Chennai, Mumbai, Pune, and Nagpur** with existing metro rail networks, as a feeder or complimentary service on low traffic routes.

Feasibility studies can be carried out for each of these cities by potential investors in ATOM.

ATOM has the potential to revolutionise urban mobility by addressing the various gaps that currently prevent public transportation in India from operating at its full potential.

**H-ATOM:** The Government of India has announced that the ‘MetroLite’ transportation system will replace the regular metro rail. It will be implemented in 50 small cities with a peak PH2DP of 15,000. This will help cut capital costs and increase financial viability. ‘MetroLite’ is expected to cost 40% less than traditional metro systems and will help provide low cost public transportation in cities.

Here is a comparison of the costs of H-ATOM against Metro projects, which are either being implemented or under the planning phase:

<table>
<thead>
<tr>
<th>City</th>
<th>Length of Metro in Km</th>
<th>Cost of Metro in Rs. Crores</th>
<th>Estimated cost of ATOM in Rs. Crores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surat</td>
<td>33</td>
<td>6,999</td>
<td>2,640</td>
</tr>
<tr>
<td>Gorakhpur</td>
<td>27.41</td>
<td>4,800</td>
<td>2,192</td>
</tr>
<tr>
<td>Visakhapatnam</td>
<td>42.5</td>
<td>8,300</td>
<td>3,400</td>
</tr>
</tbody>
</table>

Note: Cost Comparisons only for Elevated portion of Metro

**M-ATOM and L-ATOM:** BRTS in India currently operates in cities like Pune, Ahmedabad, Rajkot, Surat, Raipur, and Bhopal, to name a few. The potential for BRTS to meet mobility demand of cities is significant. However, BRTS has been successful and profitable in only limited Indian cities. The existing BRT systems can be upgraded to ATOM to provide higher operational capacity instead of upgrading to metro. This can be done wherever the demand has increased, to provide higher operational efficiency through demand-responsiveness and offer better integration with first and last mile solutions. Upgrading BRTS to ATOM would require minimum incremental investments, as only the rolling stock would need to be upgraded, and no new civil infrastructure would be required. Additionally, in cities where BRTS is under construction or in the planning phase, implementing ATOM could be considered instead. ATOM will enable private investments in public transportation and further help improve quality of service.

**Market Opportunity:** The role of the private sector in ATOM is critical in operations and maintenance. Therefore the ideal market sizing for ATOM would be in terms of the potential passenger trips per day that can be addressed by ATOM, as a public transportation service.
The addressable market for public transportation is about 79 million trips per day in 2031. This demand will be met through a combination of metro rail, BRTS, city bus, light rail and monorail. While metro would be the most preferred mode of transport in category 1 to category 5 cities. In category 6 cities, ATOM can be implemented as a feeder or standalone service on non-metro routes.

Way Forward

The proposed ‘MetroLite’ as an alternative to Metro is reported to help reduce capital costs and increase financial viability, and is expected to cost 40% less than traditional metro systems. Given the additional benefits apart from lower capital costs, ATOM can potentially be considered as an alternative to metro.

The ATOM transportation mode presented in this report offers savings on capital costs, reduces construction time, better or improves capacity utilisation, is demand-responsive and has better operational efficiency compared to both metro and light metro proposed for cities. Additionally, ATOM provides a unique opportunity for India by providing a fillip to the government’s efforts in offering world-class public transportation and leapfrog into AI-based mobility.

ATOM would help India match global technological developments in mobility while addressing the concerns being raised about driverless vehicle technology, by operating in a controlled environment and restricted to public transportation alone.

The table estimates that the total projected motorised trips in 2031 would be 327 million, an exponential increase of 140% compared to 2007. The trips in terms of kms per day are estimated to be 5,449 million. However, the key is to improve the modal share of public transportation, to ensure that the trip demand is met sustainably. According to a study by CSTEP23, the estimated modal share of Public Transportation (PT) in 2031 is as follows:

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The ATOM transportation mode presented in this report offers savings on capital costs, reduces construction time, better or improves capacity utilisation, is demand-responsive and has better operational efficiency compared to both metro and light metro proposed for cities. Additionally, ATOM provides a unique opportunity for India by providing a fillip to the government’s efforts in offering world-class public transportation and leapfrog into AI-based mobility.

To transform this concept into reality, a coordinated effort from stakeholders across industries and sectors is needed. Various critical components need to be integrated for ATOM:

- Artificial Intelligence platform for vehicle movement
- Artificial Intelligence platform for control centre
- Lithium ion batteries with higher charge cycles
- Rolling Stock or NiOs
- Standards for guideway designs, signages
- Electronic components, such as radars, GPS, IMU, cameras, LiDAR
- Artificial Intelligence platform for vehicle movement
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- Lithium ion batteries with higher charge cycles
- Rolling Stock or NiOs
- Standards for guideway designs, signages
- Electronic components, such as radars, GPS, IMU, cameras, LiDAR

Companies in India and around the globe are already pioneers in each of these elements, including the AI platform required to make ATOM a reality. Potential private sector service providers of ATOM could either develop the complete technology and components in-house or procure hardware separately while building a patented AI platform. Alternatively, they could integrate each component of ATOM on as-a-service model based on technical and commercial feasibility.

While ATOM is intended to serve as a public transport mode, the concept could be extended to other applications, such as freight transport through expressways, intra-airport terminal transportation, shuttles in restricted environments such as gated communities and universities. This can potentially unlock higher value for investors willing to develop ATOM as a solution for public transport.
Endnotes


28. “Once a corridor for buses, now just a long clothesline!”. The Times of India. November 2019

29. MMRDA, Maharashtra Government. https://mmrda.maharashtra.gov.in/mumbai-monorail-project


32. Global BRT Data, India. https://brtdata.org/location/asia/india