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Operation & Maintenance Practices in Underground vs Elevated Metro Systems

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Abstract - This study presents a comparison of operation and maintenance (O&M) practices in Mumbai's underground and elevated metro systems. It examines cost implications, infrastructure challenges, and environmental and social impacts to determine the efficiency and sustainability of each system within Mumbai's unique urban context. The findings highlight trade-offs between initial investment, long-term maintenance, and user preferences.

Key Words: mumbai metro, underground metro, elevated metro, mumbai, infrastructure, operation, maintenance.

1. INTRODUCTION *(Size 11, Times New roman)*

Metro rail networks are critical to easing urban mobility in rapidly growing cities like Mumbai. The Mumbai Metro features both underground and elevated lines, each with distinct operational and maintenance demands. While underground metros offer benefits such as reduced land acquisition and less traffic disruption, they require complex ventilation and electrical systems. MMRDA's MMMOCL looks after the Operation & Maintenance of the elevated metro systems with Reliance Mumbai Metro looking after Line 1 whereas the underground metro system's operation & maintenance is looked after DMRCA's MMRCL.

Elevated metros, though cheaper and quicker to build, face challenges like weather exposure and road space constraints. This paper explores the comparative operational and maintenance scenarios of these two systems to guide future metro planning in mega-cities.

Literature Review

1. The **Mumbai Metro Rail Systems Project** outlines Mumbai's strategy of combining underground and elevated metro lines for Mumbai's urban mobility needs & address the city's intense traffic and housing density. It discusses phased development, highlighting how elevated lines are faster and cheaper to build but may face spatial constraints, while underground lines are costlier but preserve surface space and reduce traffic disruptions.

2. The JICA study on Mumbai Metro Line 3 provides an in-depth look at operational and maintenance challenges specific to underground metro O&M. These include complex ventilation, fire safety, and electrical systems, which require specialized maintenance protocols and higher operating costs compared to elevated systems.

3. Elevated metro systems, as noted in city planning documents, often face challenges including road space reduction during construction, traffic congestion, and limited station space due to Mumbai's urban density. These constraints impact O&M activities and necessitate strategic scheduling to minimize disruption.

4. Environmental assessments show underground metros have significant life cycle impacts but offer benefits in space-saving and reduced surface disruption. This is despite higher initial environmental costs due to excavation and energy-intensive construction, offer long-term benefits by minimizing land use and surface disruption, thus aligning with sustainable urban development goals.

5. Case studies from various Indian metros highlight that O&M practices vary significantly between elevated and underground metros. Underground metros demand more advanced infrastructure maintenance and safety systems, whereas elevated metros focus on structural maintenance and weather-related wear and tear. These differences affect overall cost and operational efficiency.

As mentioned in point 2 underground metro system has some unique requirements such as ventilation system handled by last AHUs to keep the entire underground station area well ventilated as oxygen level drops in such areas which can be harmful for travelling passengers.

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(Left) A ventilation duct in a corridor. (Above) Stati platform with grills on the ceiling where ducts are installed.

The picture on the left is that of a ventilation duct installed in a corridor of a Mumbai underground metro station whereas the picture on the right shows station platform with the ventilation duct inside the ceiling.

Ventilation system is normally judged on the basis of passenger cooling capacity which is the ability t manage heat load from passengers, trains & environment to maintain a comfortable temperature. This being directly related to air conditioning is measured in Tons of Refrigeration (TR). Elevated metros systems like Line 1 normally has stations equipped with about 140 TR central air conditioning plant which scaled up significantly for Lines 2A & 7 whereas this requirement increases for underground metro system even more with more powerful 400-500 TR systems for its stations to manage the depth & passenger load.

Elevated metro stations have their own unique issues from causing a road space reduction where they're constructed as mentioned in point 3 to pigeon infestation which leads to increased problems of cleanliness due to bird droppings as well as health problems related to breathing troubles.

Nets to prevent pigeons from sitting on the roof of Ghatkopar Metro Station

Rolling Stock:

As per the commuter size different metro lines have employed different number of trains in their fleet. Elevated metros like Line 1 which the Mumbai Metro One (Ghatkopar to Versova) has a fleet of total 16 trains of 4 coaches with a capacity of about 1750 passengers while Line 2A & Line 7 has a combined fleet of 44 trains of 6 coaches with a capacity of about 2280 passengers. Mumbai underground metro on the other hand has a fleet of 31 trains of 8 coaches which is far the most by any metro system in Maharashtra & with the opening of the final phase from BKC to Cuffe Parade being now in operation it is expected to have them fully utilised during the peak hours. The trains have a capacity of about 3000 passengers each.

Mumbai Metro Train Car Shed: (Left) Line 3 Underground Metro, (Centre) Line 2 & (Right) Line 1

Power Supply Management:

Metro systems require a lot of power supply to keep its operations functioning. Just for the traction it requires 25 KV AC power supply which is provided through a 33 KV HT supply which is then stepped down via a step down transformer to the required 25 KV. Most of it comes from the grids of MSEDCL, Tata Power, etc while renewable energy like solar power also contributes significantly. The back up power is based on Uninterruptible Power Supply & Diesel Generators.

Main power supply for Mumbai underground metro system as well as for the elevated Line 1 is TATA Power whereas for elevated metro systems like Line 2A & 7 also being TATA Power is about change to Adani Electricity as MMRDA has decided to switch to a cheaper as supplier.

DG on road level under a Line 1 metro station

Along with regular sources renewable energy such as solar power is also used by installing solar panels on top of the roofs of stations & depot buildings. Although this has been an especially unique feature of elevated metro systems whether Line 1 or 2A & 7 due to their exposure to direct sunlight. This energy is meant for lighting, air conditioning, escalators, lifts, etc.

In case of any power failures the back-up power supply system is generally the same in both the underground metro system & the elevated metro system which Uninterruptible Power Supply (UPS) which runs on already charged batteries. These UPS run within milliseconds of power failure & keeps running for a limited period while the main back-up power supply starts which the Diesel Generator (DG). A DG will keep proving power supply either till the main power supply is restored or the DG runs out of fuel.

Cost Implications:

O&M Factor	Underground Metro	Elevated Metro
Energy Costs	**Very High** (Ventilation, Cooling, Lighting)	**Lower** (Natural ventilation/lighting)
Infrastructure Maintenance	**High** (Complex, inaccessible systems)	**Moderate/High** (Weather-related structural upkeep)
Vulnerability to Weather	**Very Low**	**High** (Service disruptions, ice/snow removal)
Access for Repairs	Difficult & Disruptive	Easier & Faster
Noise Mitigation	Not Applicable	Ongoing Cost

Energy cost: Due to large ventilation & cooling system as well as 24/7 lighting the underground metro system has a higher energy cost. The elevated metro system on the other hand has natural ventilation & natural light during daytime which reduces its energy cost in comparison.
Infrastructure maintenance: If the underground stations are deeper then the vertical transport can be longer which requires longer escalators & lift operations which are costlier to maintain. Elevated stations have different structural maintenance requirements such as the upkeep of support pillars & open tracks.
Weather impact: Underground metro stations are less vulnerable to weather impacts though preventing the stations from being flooded during heavy rains in areas where waterlogging can be a problem is its biggest challenge. Elevated metro stations are exposed to weather impacts & are therefore more vulnerable to natural elements such as rain causing leakages from roofs & heavy winds blowing through the open platforms.
Access to repair: Doing repair & maintenance work in underground tunnels is more difficult compared to easily accessed elevated structures.

CONCLUSIONS

Underground metro systems in Mumbai require more complex and costly operations and maintenance due to higher electrical loads, ventilation, and safety needs, especially for escalators and elevators. Elevated metro systems are simpler to maintain but face challenges like weather exposure and space constraints.
Although they consume a lot of power generated by conventional sources they're committed to make use of non conventional energy sources such as solar power as much as possible. They both face different but also some similar challenges, both kind of metro systems having their pros & cons are essential in their particular circumstances given the unique needs of the city of Mumbai.

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