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AI - DRIVEN INNOVATION FOR LOCAL RAILWAY SYSTEM IN MUMBAI METRO REGION FOR TRANSFORMATIVE URBAN RAIL SYSTEM

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1. INTRODUCTION

Mumbai, India's financial capital, relies heavily on its suburban railway system to sustain daily urban life from travelling for work or business, medication or leisure. Often described as the city's "lifeline," the Mumbai Suburban Railway carries over 80 lakhs passengers per day, making it one of the busiest rail networks globally. The system supports economic productivity, social mobility, and spatial integration across the Mumbai Metropolitan Region. However, extreme passenger density, aging infrastructure, safety concerns, and service disruptions pose chronic challenges.

Traditional approaches to railway improvement in Mumbai have focused primarily on capacity expansion and incremental technological upgrades. While such measures are necessary, they may be insufficient to address the volume of problems faced by passengers in day to day travelling. At the same time, artificial intelligence (AI) is emerging as a general-purpose technology with the potential to fundamentally reshape transport systems through automation, data analytics, and real-time decision-making. Indian planning includes Digitalisation however, it lacks automation.

This paper advocates that AI adoption in Mumbai's railway system should be understood not merely as a technological upgrade, but as an innovation process embedded within a broader socio-technical, environment friendly system. Using innovation suggestions as a guiding principle, the paper recommends how AI-driven innovation can enable transformative change in Mumbai's urban railways. The focus is on theoretical aspect rather than operational testing, with the aim of providing textual clarity for future research and policy interventions.

2. REVIEW OF LITERATURE

- Joseph S. (1934)[1] in his book "The Theory of Development" published by Havard university press, has suggested economic and finance flow for an organisation of public in nature (in this context railways system). He advocated that finance will flow to such public sector unit with the help of Public Private Partnership. And it can speed up the process of innovation and technological transformation.
- Frank W G. (2002)[2] In research paper, "Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study" described a new perspective, based on insights from evolution, economics and technology studies. his insights have been synthesised in a multi-level perspective consisting of three levels: technological niches, sociotechnical regimes, sociotechnical landscape. This perspective combines two views on evolution. He emphasised on niche level studies and problem-solving methods for systematic innovation
- Charles Edquist's (2011)[3] in his article, "Design of innovation policy through diagnostic analysis," published in *Industrial and Corporate Change*, suggested a framework for creating effective innovation policy by first diagnosing systemic problems or failures within an innovation system, in his article he argued that instruments must be tailored to address specific identified issues for successful innovation and policy design. The paper advocated that innovation cannot be attain by generalised theories. It needs to pinpoint deficits in innovation activities like R&D, financing, or institutions to create targeted, systemic policy mixes
- Prajakta P. et al. (2018)[4] in their paper "Efficient Train Management System - An AI Approach" published by International Journal of Science and Research, their paper gives an overview of how Artificial Intelligence can be used to improve efficiency of the system by providing a dynamic timetable to make trains less crowded. This can be done through analysis of Historical Data to identify reasons for issues such as delay in trains, overcrowding, etc. On the basis of this analysis, a model for efficient train allocation and time table management is proposed. Furthermore, the viability and application of the model is also proposed in this paper.

3. RATIONALE BEHIND THE STUDY

Innovation theory has evolved from linear models of technological progress toward more systemic and interactive perspectives. Contemporary innovation theory emphasizes that innovation emerges from interactions

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among multiple sectors, including business organisations, governments, commuters, and knowledge institutions. Technological change is shaped by institutional structures, regulations, cultural norms, and market dynamics. In the case of railway systems in India, innovation extends beyond new technologies to include organisational practices, governance models, and service design. Railways, particularly Mumbai local trains deeply influence in political and social contexts, making innovation a complex and bureaucratic process with red tapism at each stage. Socio-technical transition theory provides a useful conceptual framework for understanding long-term change in large infrastructure systems such as railways. This perspective highlights interactions between three levels: niche innovations, dominant regimes, and broader socio-economic landscapes.

4. OBJECTIVES OF STUDY

Following are the objectives of the study:

ii. To analyse current systems for innovation in Mumbai Railway

iii. To formulate theories for innovation in Mumbai local railways

iv. To suggest framework to attain innovation through Artificial Intelligence.

5. RESEARCH METHODOLOGY OF THE STUDY

To understand the present study the information has been collected through secondary sources only. The secondary data has been gathered from sources such as the Internet, reference Books, Newspapers, Journals and mobile applications etc. Data collected is compiled to state observations, conclusion and suggestion.

6. CHALLENGES

- **Problem of Processing large amount of data:** Mumbai railways have large volumes of data generated from sensors, ticketing systems, CCTV footage, and mobile applications. In Mumbai's context, such data can support real-time monitoring of passenger flows, early detection of equipment failures, and optimized train scheduling. However, there is no mechanism to process the data and solving problem
- **Problem of overcrowding, safety and operations:** Safety is a critical concern in Mumbai's suburban railways, given high levels of overcrowding and frequent accidents. In spite of CCTV, RPF and other human resources available on platform and in train, there is no mechanism to manage the same or an alert for overcrowding or over speeding
- **Bureaucracy in railway:** Railway being in concurrent list of constitution, all policy implementation has to go through various government authorities like State government, Central government, Local Authorities (BMC), and Service provider institutions. This slows down the process of innovation and also involve corrupt practices.
- **End user suggestions:** Passengers in Mumbai's railways are not passive users but active participants who adapt, improvise, and develop informal practices to cope with congestion and delays. However, their suggestion, ideas and innovations are never analysed or implemented by respective authorities.

7. RECOMMENDATION

Improve AI Capabilities

This includes machine learning, computer vision, and predictive analytics applied to operations, maintenance, safety, and passenger services by railway authorities.

Innovation in Operational Practices

Drawing from innovation theory, these mechanisms include experimentation, learning-by-doing, Public Private Partnership, and feedback analysis loops between users and operators.

Decentralisation of decision making

Regulations, labour relations, funding models, and inter-agency coordination may improve the speed and direction of AI adoption in railway.

Much Needed in Metropolitan Cities

Extreme population density, socio-economic diversity, and informal mobility practices in Mumbai influence both the problems AI seeks to address i.e. analysis and interpretation. Without which innovation cannot take place at the pace we need in city. The framework suggests that AI-driven railway innovation succeeds when technological capabilities are aligned with institutional readiness and urban realities. Innovation is therefore not a purely technical process but a socio-technical transition requiring coordinated change across multiple dimensions.

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8. SUGGESTIONS

- **Railway driven by data and AI**

Artificial intelligence enables railways to shift from reactive to predictive and adaptive operations. Machine learning algorithms can analyse large volumes of data. AI transforms the railway into a learning system that continuously adapts to changing conditions. This represents a qualitative shift from traditional rule-based operations to data-driven decision-making.

- **AI Video Analytics**

AI-enabled video analytics and pattern recognition systems can help identify risky behaviours, overcrowded platforms, and unauthorized track crossings. From an innovation theory perspective, safety-oriented AI applications can act as "mission-driven innovations" that align technological development with public value creation.

- **Co-operation and Co-ordination**

Innovation theory suggests that successful technological adoption depends on institutional capacity and coordination. Fragmented governance structures may slow innovation, while collaborative platforms and public–private partnerships can accelerate AI deployment

- **Analysing end user data**

Digital platforms, such as mobile applications providing real-time train information, create opportunities for user feedback and co-creation. Conceptually, involving users in AI-enabled service design aligns with interactive innovation models, where knowledge flows between service providers and service users enhance system performance and legitimacy.

9. Conclusions

Mumbai's railway system stands at a critical stage where incremental improvements may no longer be sufficient to meet increasing commuters demands. This conceptual paper has argued that artificial intelligence, when understood through the point of view of innovation theory, offers a pathway toward transformative change. By conceptualising AI adoption as a socio-technical innovation process embedded in Mumbai's unique urban context, the paper provides a holistic framework for understanding both opportunities and constraints. The future of Mumbai's railways depends not only on advanced algorithms but also on institutional capacity, user engagement, and governance innovation. As metropolitan city worldwide confronts similar challenges, insights from Mumbai can contribute meaningfully to global debates on AI-driven urban transport innovation.

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