AI in Indian Railways – Applications and Challenges

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ABSTRACT:

The Indian Railways is one of the largest national railway system in the world. It is one of the most preferred system of transportation of people and goods. Due to higher demand for mobility and growth in India's population over past several decades, the pressure on the Indian railway networks has increased. With the rise in passengers and cargo volumes, it has a mammoth of tasks to perform. These could be train operations, scheduling, track maintenance, other repairs and maintenance, ticketing, signaling, catering services, rolling stock, etc. There is a need to improve the efficiency of its operations as well as enhance safety and security of its services. Since its functioning from 1853, it has been used to perform functions and services manually. But in the present days manual work will not suffice. With the advent of digitalization all over the world and different spheres of activities, new ways to operate must be looked into. Artificial Intelligence (AI) is becoming pervasive in many domains, and railway transport is no exception. The scope of this paper is to find out the possible applications of AI by Indian Railways covering a broad range of AI fields and various domains in infrastructure maintenance and inspection, safety and security if passengers and goods transported and railway property, operational efficiency, punctuality, revenue management, passenger services and the like and various challenges which introduction of AI in Railways would face. The aim is to improve customer/passenger experiences and generate more revenue while paying attention to environmental sustainability.

KEYWORDS: Artificial Intelligence, Ask DISHA**,** Indian railway, sense-analyze-respond, signaling, USTAAD

INTRODUCTION:

Indian Railways under the aegis of the Ministry of Railways, Government of India, constitutes the backbone of the nation's transportation infrastructure Spanning over 70,000 kilometers of tracks and orchestrating a network of more than 20,000 passenger trains, it ranks as the fourth-largest railway system globally as of April 2019.

Over the past 150 years, Indian Railways has remained an indispensable lifeline for countless individuals, offering inclusivity across diverse demographics. In a world evolving with air travel and expressways, Indian

Railways maintains its enduring significance as the primary mode of mass transit for both people and goods. However, as passenger and cargo volumes surge, optimizing operations and bolstering safety and security have become pressing concerns. The complexity of managing an extensive railway network, encompassing intricate schedules, multifaceted routes, and the coexistence of passengers and freight traffic, presents formidable challenges.

Traditionally reliant on manual labor, Indian Railways is vulnerable to human errors that can have far-reaching consequences, particularly on this grand scale. Efficiently managing every facet, from operations and maintenance to scheduling and monitoring, has proven toilsome.

Indian Railways embarks on a comprehensive modernization endeavor, involving complete electrification, high-speed track construction, and the creation of tunnels, bridges, and infrastructure. Protecting this extensive and forthcoming infrastructure from operational and security hazards is imperative. With tens of thousands of kilometers of tracks and daily train movements, achieving this consistently and efficiently through human effort alone is unfeasible. This is where advanced technologies and artificial intelligence (AI) come into play as catalysts for transformation. Indian Railways started using AI since around 2018.

AI integration across operations, emphasizing safety, security, preventive maintenance, efficiency, punctuality, and ticketing, has become imperative. As Indian Railways propels towards a digitalized, cashless future, AI emerges as a pivotal enabler. It promises an array of services, ranging from managing train operations and facilitating ticket bookings to maintaining systems and overseeing railway assets. In the ever-evolving landscape of rail operations, AI and machine learning are no longer optional but essential. Indian Railways stands at the precipice of a transformative journey, where AI will be instrumental in overcoming the escalating complexities of the rail industry.

REVIEW OF LITERATURE:

Chandrika Prasad and Sudhanshu S Jamuar (2021)[2] in their paper highlighted the potential contributions of AI towards improvement of India's railway system and how the application of recent technological advancement, especially AI can bring about a change in the way in which the railways function at stations and control center and make it more profitable.

Besinovic, N., De Donato, L., Flammini, F. and 7 more authors (2022)[1] in their paper presented a structured taxonomy to guide researchers and practitioners to understand AI techniques, research fields, disciplines, and applications, both in general terms and in relation to application of AI in railways like autonomous rails, maintenance and management of train traffic. The important aspects of ethics and explainability of AI in railways too were discussed.

Almost negligible research has been undertaken on applications of AI in Indian Railways. Most of them explored only few uses to which AI is applied by the Railways. Neither the future nor the challenges have been looked into. An attempt is made is this paper to include all missing.

OBJECTIVES OF THE STUDY:

1. To study the uses of AI in Indian Railways.
2. To understand the challenges and issues related to use of AI in Railways.

RESEARCH METHODOLOGY:

The research is done on Indian Railways. It is mainly a desktop research and the researcher has used only secondary sources of data, namely online sources for newspaper news, research journals, articles, etc. to understand the applications and challenges of integrating AI with railways. To authenticate whether there has been an improvement in operation and services of railways after the introduction of AI in around 2017, primary data was used. 200 Frequent travelers, i.e., those who travelled at least 12 times a year, were asked questions relating to ticketing, safety, timeliness of trains, services of trains, etc. after the introduction of digitalization and apps. For this primary data was used. Questionnaires were sent in google form and the first 200 filled google forms received were analysed.

DATA ANALYSIS:

A. Analysis of Primary Data

Out of total 200 respondents who were frequent commuters in trains, 157 were male and only 43 were female responses were analysed.

Table No. 1: Responses on Various Parameters of Railway Improvement

Parameter	Question	Male		Female		Total		
		Yes	No	Yes	No	Yes	No	Total
Safety	Number of train accidents have decreased	154	03	39	04	193	07	200
Timeliness of Trains	Trains run on time and reach destination on time	02	155	02	41	04	196	200
Ticketing	Booking tickets have become less cumbersome	128	29	37	06	165	35	200
Services	1. Catering services improved	119	38	35	08	154	46	200
	2. Cleanliness of coaches has increased	139	18	37	06	176	24	200
	3. Cleanliness of toilets have improved	137	20	36	07	173	27	200

Graph No. 1: Responses on Various Parameters of Railway Improvement
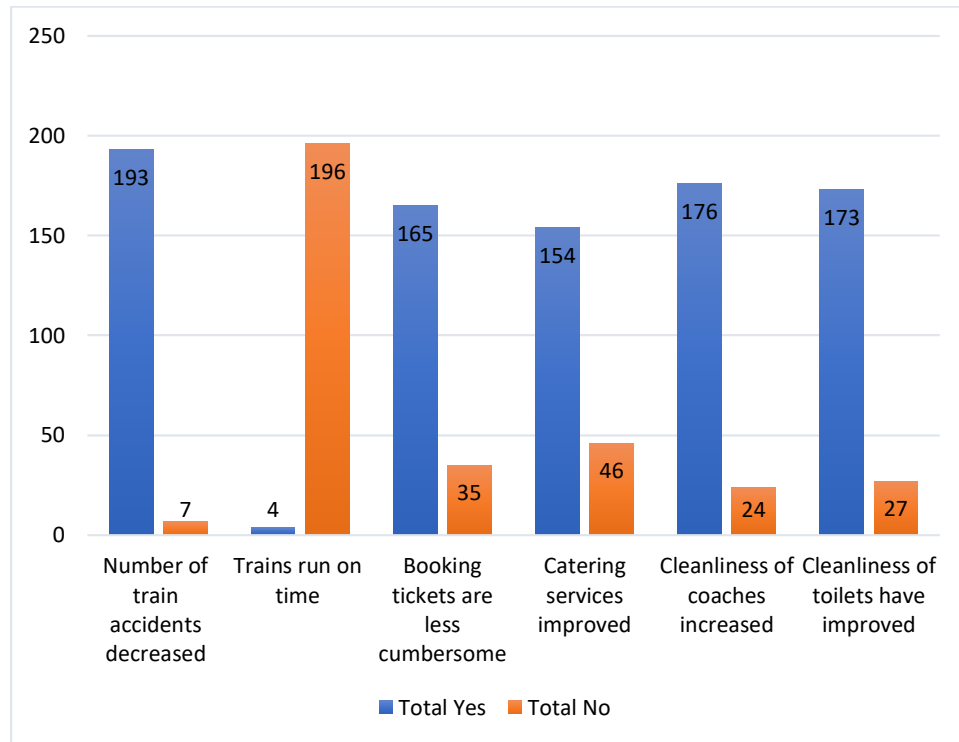
In addition, they were asked to mention any other issues, problems, etc. related to the above questions. In general not much difference was found in the opinion of male or female traveler.

1. **Safety:** Train accident numbers have gone down, is what 96.5% of the respondents felt. The data available online too shows a decrease in the number of accidents over the decade.

Graph No. 2: No. of Train Accidents in India From Financial Year 2014 to 2022 No. of Accidents
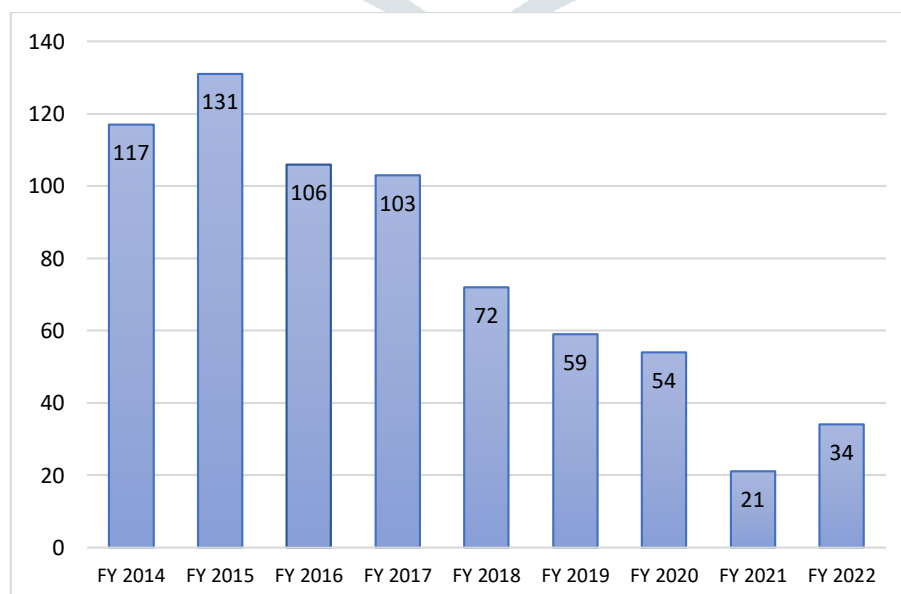
Source: https://www.statista.com/statistics/1029503/india-train-accident-

number/#:~:text=The%20number%20of%20train%20accidents,infrastructure%20developments%20and%

20technological%20advancements

The source also states that the number of train accidents across India was 34 at the end of financial year 2022. This has been accorded by railways to the various infrastructural and technological developments.

2. **Timeliness of Trains:**

98% of the respondents agreed that train punctuality has not improved.   In fact, they also complained that their whole schedule is disturbed due to trains running late.   In the Economic Times dates 22nd August, 2023, there was news of decline in punctuality of mail and express trains by almost 73 per cent by mid-August in 2023-24. There has also been a reduction in the speed of goods trains.

The reasons of   lack of punctuality of trains in the last few years was attributed to failure of signal, lack of track maintenance, increased number of trains, continuous construction projects. As per Railway authorities this is due to heightened emphasis on track maintenance and allocating necessary time blocks for both new and upkeep works. They do not want to compromise regarding ensuring proper blocks for safety and asset maintenance. Stop signals are not stricticty adhered to.

3. **Ticketing:**   In all, 82.5% of the respondents stated that over the years booking through websites like IRCTC, Make My Trip, etc. has made booking of tickets less cumbersome. Waiting in lines are a passe. Waiting lists too are cleared and in current booking one gets berth, if there is vacancy. Tatkal booking too is beneficial, though available at a higher price. But they complained about IRCTC server being down at times or taking time to open.

4. **Services:** Majority said yes when asked about the catering services, cleanliness of coaches and toilets. Earlier there was shortage of bedrolls, but since last two to three years, the instances of shortages has gone down. Outsourcing is done for cleanliness too. Mobile numbers of complaints have been displayed and on complaint they are present for cleanliness in a few minutes.

Various apps like Where is my train, IXIGO, etc. for train tracking, train routes, PNR status, ticket booking, etc. have been developed. Many are not aware of these apps and many not using it due to lack of knowledge of how to use it, especially those who travel less frequently. The penetration of use of these apps are not as it should have been.

B.   Analysis of Secondary Data

Artificial Intelligence (AI) has emerged as a transformative technology with immense potential for Indian Railways. This analysis explores various applications of AI in the railway sector, focusing on its current uses and future possibilities.   Below are a few areas where use of AI in Indian Railways would lead to smoother operations and vast number of areas waiting for improvement through the use of AI.

Current Applications of AI in Indian Railways:

1.   Track Maintenance Blocks:

AI has been employed in July 2018 to diagnose the condition of rail tracks, leading to improved punctuality by planning maintenance based on AI-aided calendars. The repair and replace calendar developed by AI technology ensures the timely upkeep of tracks, contributing to smoother operations.

2.   Railway Signaling System:

The signaling system of the railways, which controls train movements to ensure safety, efficiency and timeliness of trains, since long has been based on physical signals placed beside the track to communicate with the train driver. These signals are coloured lights, semaphore arms, etc. However, since November 2017 AI is being used to monitor and improve the railway signaling system. Indian Railways commenced the remote condition monitoring of the signal system to predict failures by data transfer through a wireless medium (3G, 4G, and high-speed mobile) and data based on these inputs will be utilized, with help of AI for predictive and prescriptive Big Data analytics using AI.

3.   Live Tracking of Trains:

Without proper schedules, chaos would ensue. For live tracking of train by railways and the passengers, the former have collaborates with Indian Space Research Organisation (ISRO). The railways are also trying to install satellite navigation (Satnav) and communications (Satcom) based IoT devices on the trains to provide autonomous geo-positioning. Busiest routes and times could be determined with the help of advanced data visualization tools.

4.   Tackle Long Waiting Lists:

It has come to our attention that the demand for accommodation on trains does not follow a uniform pattern, but instead exhibits significant variations based on factors such as the train's origin-destination pairs, departure times, class preferences, and the availability of alternative transportation options. To address this issue, Indian Railways introduced AI program designed to alleviate the challenges posed by long waiting lists. This innovative approach replaces the conventional practice of analyzing historical data for individual trains or similar ones on a specific route. AI-driven programs like the 'Ideal Train Profile' analyze demand patterns and optimize seat allocation, increase train occupancy, reducing waiting lists and enhancing passenger satisfaction.

5.   AI Virtual Assistant of IRCTC

Ask DISHA, an AI-based chatbot on the IRCTC, allows users to book tickets, check refund, train and PNR statuses, tatkal timings, train fares, and address queries via text messages, voice and chat. It also provides information on e-Catering and tourism as value added services. Working 24x7, it has Auto response and zero waiting time for enquires.

6.   AI-Enabled Music Service

Collaboration of Hungama with AI startups like CoRover in March 2019 allows passengers to access video and audio streaming services through AI-enabled chatbot Ask Disha, enhancing the passenger experience.

7. AI-enabled Robots for Safety

To give 360-degree views by capturing photographs and videos and detecting train faults, the Indian Railways introduced AI powered robot USTAAD – Under-gear Surveillance Through AI Assisted Droid. It can enhance safety by detecting faults in trains and providing real-time information to authorities.

8. AI and ML Powered Travel Apps

Machine learning-powered apps like RailMitra was launched in September 2018 which offers various services, including train status updates, PNR checks, food orders, seat availability information, chances of confirmation and railway timetable.

9. SMART Coaches

The Indian Railways introduced SMART Coaches in August 2018. SMART coaches with AI-based systems monitor train health, predict maintenance needs, and improve security standards, contributing to passenger safety.

The SMART coach features Wi-Fi with real-time information, a vibration-based sensor for wheel and track defect prediction, and an AI-powered CCTV system to enhance security and monitor railway staff behavior, aiding incident tracking.

10. Catering Services

In May 2018, Indian railways initiated the process of adopting AI systems known as Wobot to improve catering services by monitoring compliance with hygiene standards. Wobot's AI SaaS tool integrates seamlessly with existing CCTV cameras to ensure vision-based process compliance, detecting anomalies throughout the catering operation, such as non-compliance with uniform requirements by chefs or kitchen supervisors, including the mandatory cap. If there are irregularities, automatically report will be sent to the mobile of the concerned contractor immediately. Failure to address the matter within 15 minutes triggers a report to IRCTC authorities. If no action is taken at that level, it escalates to the IRCTC MD. Customers can select industry-specific compliance modules (e.g., hygiene, workforce safety) for existing cameras to automatically flag deviations to relevant stakeholders and provide a dashboard with insights.

11. Prevent Elephant Collisions

In the last financial year 2022-23, Northeast Frontier Railway has signed a Memorandum of Understanding (MoU) with RailTel Corporation of India Ltd, for installation of AI-based Intrusion Detection System (IDS), based on Artificial Intelligence (AI) and existing optical fibres to avert train-elephant collisions on railway tracks. These systems act as sensors to detect wildlife movements and notify control offices, station masters, gatekeepers, and loco pilots. The AI-based software can monitor unusual activity within a 60 km stretch. Furthermore, the IDS aids in identifying rail fractures, trespassing on tracks, and provides alerts for disaster mitigation, including unauthorized digging near tracks and landslides.

Future Potential and Emerging Applications:

1. Restricted Area Monitoring and Access Control

AI tools utilize integrated CCTVs to monitor railway facilities, tracking visitors, and detecting unauthorized individuals in restricted areas, such as control rooms, maintenance sites, and under-

construction projects around the clock. Using facial and vehicle number plate recognition, these cameras determine if access is authorized, issuing warnings through public address systems for suspicious individuals or illegally parked vehicles.

2. Tunnel Security

Tunnels, that play a critical role in taking the railways through the mountainous terrain, can also be a security risk. AI surveillance plays a crucial role in tunnel safety by detecting the presence, location, and movement of individuals, as well as monitoring train speed and halts. It can also identify theft or object removal that may endanger train safety in the area. In the event of smoke or fire, video cameras swiftly recognize the incident and alert security personnel to prevent its escalation.

3. Trespassing Prevention

AI-integrated CCTV networks can act as intruder alert systems, preventing unauthorized access to railway premises. Such systems would alert the security teams or deny access to the trespassers or act as a tripwire to prevent trespassing.

4. Manipulation of CCTV Systems

AI can enhance surveillance capabilities by detecting operational problems or tampering with CCTV systems. AI integrated video analytics has the ability to to inform whether a camera's video signal is lot or the view of the camera is blocked, viewing angle is changed or the camera is defocused/blurred causing disruption in the video monitoring abilities thereby alerting the technicians and security teams who can quickly respond and rectify such problems.

5. Pre-Boarding Experience

AI can be utilized to assist passengers with booking tickets in their preferred languages by speaking, recommend suitable trains. It can allocate platforms based on passenger demographics and needs. AI can optimize platform assignments based on passenger demographics, ensuring convenient access for groups like the elderly or pregnant women. By analyzing passenger data for trains at a given time, AI can determine optimal arrival/departure platforms, enhancing crowd management. It also employs image recognition to alert authorities if the platform crowd exceeds ticket limits, facilitating efficient oversight. After that, appropriate actions can be taken. AI can monitor platform crowds and alert authorities if ticket limits are exceeded, improving passenger safety.

6. Onboarding Experience

Despite the view outside the window, the peddlers on the platform, and other nostalgic references, train travel bring with it its own share of anxieties and inconveniences like berths in different coaches, missing the destination station early in the morning, safety from ticketless travelers and vendors and their nuisance. With AI, most of these issues can be accurately diagnosed and patterns can be established. With facial recognition as evidence, the penalty for ticketless travelers could be Supported by facial recognition evidence, the amount of punishment/penalty for traveling without a ticket may be unduly increased in certain segments to prevent occurrence of such instances. AI could also help figure out patterns and handle the problem of unauthorized travelers and street vendors entering the train, if it doesn't completely solve it.

7. Post-Deboarding Experience

Those visiting the railway station for the first time could be troubled with confusion, commotion and be bothered by taxi drivers. AI can automate post-trip arrangements, such as assignment of porters, booking taxis and hotels, based on passenger information like age, final destination, luggage, etc., for a price included in the ticket. This will enhance the overall travel experience. Post-disembarkation services not only make travel convenient for passengers but also add revenue channels to rail.

8. Inventory Management

Keeping records of maintenance of rail equipment manual not only consumes a lot of time but there could also be chances of human error. AI can automate maintenance alerts, improving inventory management, and ensuring safe travel by preventing accidents. Digitized records would be more efficient as well.

9. Crew and Human Resource Management:

Crew Management could be done effectively. AI-driven adaptive approach can ensure that the operating personnel in each railway section can adhere to the timetable or schedule by optimizing Crew Rostering i.e., long-term distribution of personnel at various nodes of the network and Crew Scheduling which involves a short-term planning problem. Difficult combinations of capacity, preferences of crew, rest periods, overnight stays, etc. can be efficiently managed through AI. Apart from these, AI would be of help in managing staff data and their payrolls.

10. Data Management:

Cloud-based AI technology aids in storing and managing the vast amount of data generated by the rail industry. This ensures cost savings, steady accessibility, and integration with other software for informed decision-making.

11. Biometric Ticketing:

AI-powered biometric ticketing systems, including retina scans, facial recognition, and vein scans, enhance security, reduce overcrowding of passenger at train platforms, and eliminate the need for traditional ticket counters. Companies like Customer Clever and the Bristol Robotics Laboratory in the UK are pioneering this system, which is immune to photo manipulation, capable of distinguishing identical twins, and proficient at recognizing individuals wearing glasses. It can even identify people in motion, potentially eliminating the need for traditional ticket gates at stations.

12. Predictive Maintenance for Operational Efficiency

Rather than periodic maintenance, predictive asset maintenance continually monitors equipment condition, issuing alerts as needed. AI analyzes sensor data to predict failures and recommend proactive maintenance, reducing downtime and enhancing reliability. Parameters like temperature, vibration, wear, etc. can be monitored with the help installing sensors on trains. Timely identification of potential maintenance issues, in turn helping reduce breakdowns, reduce in cost of maintenance costs and cut down load on maintenance of assets and improve overall reliability of the system.

13. Autonomous Trains

Passenger and freight trains are gearing up for fully autonomous operations. Currently, driverless trains run on separate lines, and autonomous systems are utilized in subways worldwide, driven by artificial intelligence. In

India, the Delhi Metro stands as the sole fully automated network, covering about 97km on the Pink and Magenta lines. These intelligent solutions bring numerous advantages, including enhanced safety, breakdown prevention, cost reduction, improved punctuality, and increased passenger comfort.

14. Punctuality

Currently, railway networks do not use automated algorithms for functions like time duration from the first event to the last event, total or average running or priority-weighted time of trains, robustness of the timetable to deviations, and combinations thereof to ensure that either a track section between two stations is occupied by at most one train at a time (in absolute block signaling), or every piece of track between two signals is occupied by at most one train at a time (in automatic block signaling).

Use of algorithms, simulation models, graphs, and control systems with the required degree of AI in Indian Railways approach will generate high-level and microscopic timetables and schedules of train movement. It will help in listing the tracks to be occupied, time required for switching tracks, requirements for signaling and evaluating parameters of immediate conflict, thereby enabling instance scheduling decisions.

Use of AI will help controlling the speed profiles of trains. It will help detect obstacles on the tracks and help predict train delays caused due to train priorities, downstream conflicts with other trains, freight loads, and irregular stopping times and reduce such instances. It is impossible for human beings to process all factors leading to train delays or coming up with an optimal solution for the railway network.

The program operates in three stages: 'sense,' which collects train network data; 'analyze,' which assesses potential outcomes; and 'respond,' which assigns track resources to trains according to physical capabilities and safety standards.

15. Environmental Sustainability:

AI can optimize energy consumption, reduce emissions, and improve efficiency, contributing to a reduced carbon footprint for Indian Railways and thus can have a positive environmental impact.

CHALLENGES TO AI IN INDIAN RAILWAYS:

Implementing Artificial Intelligence (AI) in the Indian Railways system holds immense potential for enhancing efficiency, safety, and passenger experience. But the journey of transformation from manual system to AI has certain challenges. The complexity of the railway network, regulatory compliance, and the need for seamless integration with legacy systems present formidable obstacles that must be addressed.

1. **Complexity of algorithms:** The Indian Railways system is vast and multifaceted, encompassing various services such as passenger trains, freight transport, maintenance, and scheduling.

2. **Complying with the government regulations:** The Indian Railways operate within a highly regulated environment. Any AI solutions must adhere to government rules and safety regulations, which can be a challenging hurdle as the complexity of AI systems increases.

3. **Adherence to operating rules, procedures, and constraints:** AI systems must be designed to operate within the constraints of real-world railway systems. They have to be area specific, as per zones created by railways like Central Railway, Eastern Railway, etc. They must account for operating rules, safety procedures, and network-specific constraints while making decisions.

4. **Easy application:** AI solutions should be designed for easy application across different railway network segments without the need for extensive retraining. This universality ensures that a scheduling algorithm developed for one part of the network can be seamlessly applied elsewhere, maximizing the efficiency of AI systems.

5. **Flexibility:** Railway problems differ in complexity, with varying numbers of inputs and decision points. Many AI techniques have fixed input-output sizes, making it necessary to adapt them to accommodate diverse problem instances. Various permutations and combinations/problems must have similar solution on source platform. This flexibility requires significant time and effort in algorithm design.

6. **Need for detailing:** Safety-critical railway applications demand transparency and reliability. Blackbox AI approaches may not be suitable for such contexts. Blackbox for each coach or engine or train route will have unique or specific requirements. Data may be useful but clutter of information may create confusion. Hence Blackbox approach MA not be viable at present.

7. **Interoperability (Integration with legacy systems):** Large sharing of data requires closer collaboration. This includes operations, communications, and integration of data amongst different models and manufacturers. Integrating AI systems with existing railway infrastructure, which may consist of legacy systems, poses a significant challenge. Legacy systems often use outdated technology, file formats,

programming languages and communication protocols. Compatibility issues and data integration hurdles must be resolved to create a cohesive AI-enabled railway ecosystem.

8. **Data quality and privacy:** AI systems heavily depend on high-quality data to function effectively. Maintaining data quality can be challenging due to various factors, including sensor malfunctions or data corruption due to environmental factors, or human error. Moreover, railway operators must adhere to stringent data privacy regulations to protect sensitive information, such as passenger data and train schedules.

9. **Cost and complexity:** Implementing AI in the Indian Railways system requires a significant investment in terms of infrastructure and technology upgrades.

10. **Unemployment:** Use of AI will lead to unemployment of especially unskilled labour.

RECOMMENDATIONS:

1. To overcome the complexity of algorithms, developing AI algorithms capable of handling the diverse inputs and requirements of these services is a formidable task. These algorithms must account for factors like train routes, weather conditions, maintenance schedules, and passenger preferences, increasing their complexity and development time.

2. Ensuring that AI implementations meet government regulatory standards is crucial for their acceptance and reliability.

3. To adhere to operating rules and constraints, meticulous integration and validation of AI models with railway operations to prevent errors and ensure safety is required.

4. Blackbox will have to be tailor made as per specific requirements of the prevailing systems. Instead, machine learning approaches like decision trees or neural networks with well-defined input-output sizes are needed to ensure transparency and accountability.

5. For interoperability, compatibility issues, data formats, and communication protocols are some of the challenges that need to be addressed to ensure seamless integration.

6. While these investments promise long-term benefits like reduced operational costs and improved safety, the initial costs and complexities of modification must be carefully managed.

7. Create consciousness among all staff regarding the AI as AI will not totally replace human staff at least for near future.

8. Appointment of skilled staff will be required.

9. Retrain the existing staff to be well equipped to handle the amalgamation of AI in railway systems.

10. Signals can be designed to work dynamically based on the situation rather than on a set pattern.

CONCLUSION:

Every field in India has started used various technologies to improve their efficiency. The railways could not stay behind. AI holds enormous potential for Indian Railways, both in current applications and future possibilities. From improving safety and efficiency to enhancing passenger experience and environmental sustainability, AI is poised to revolutionize the railway sector, making it more advanced and passenger-friendly.

Continuous innovation and investment in AI technologies will be essential for realizing these benefits and transforming Indian Railways into a world-class transportation system.

However, addressing the challenges of complexity, regulation compliance, interoperability, safety, data quality, and cost will be critical for successful implementation. Overcoming these hurdles will pave the way for a more efficient, reliable, and passenger-friendly railway network, benefitting both the economy and the citizens of India. While the Indian government has demonstrated a commitment to fostering a conducive environment for technological advancement in railways, there are challenges that must be addressed. These include the substantial investments required, infrastructure upgrades, and the need for a skilled workforce to implement and maintain these advanced systems. However, it is essential to acknowledge that the full-scale adoption of AI-based train systems will take time, possibly spanning decades.

In summary, the integration of artificial intelligence (AI) and emerging technologies in the Indian railway industry represents a transformative opportunity with immense potential. With proper investments, upgrades, and a skilled workforce, the railway system can evolve into a more efficient, safer, and passenger-friendly mode of transportation. The future of Indian railways is undoubtedly intertwined with the evolution of AI and emerging technologies, promising a brighter and more technologically advanced era for rail travel in the country.

REFERENCES:

1. Bešinović, N, De Donato, L, Flammini, F (7 more authors) (2022). *Artificial Intelligence in Railway Transport: Taxonomy, Regulations, and Applications*. IEEE Transactions on Intelligent Transportation Systems, 23 (9). pp. 14011-14024, ISSN 1524-9050.
   Online: https://eprints.whiterose.ac.uk/180822/6/AI_taxonomy_paper_%28accepted%29.pdf

2. Prasad, Chandrika and Jamuar, Sudhanshu S. *Optimising Indian Railways Infrastructure by AI*. pp.202-210 Online: https://www.riverpublishers.com/pdf/ebook/chapter/RP_9788770222174C22.pdf

3. https://analyticsindiamag.com/how-indian-railways-uses-ai-a-comprehensive-case-study/

4. https://byjus.com/question-answer/what-are-some-of-the-challenges-faced-by-indian-railways-ticketless-travelling-by-the-passengers-1/

5. https://data-flair.training/news/artificial-intelligence-in-indian-railways/

6. https://economictimes.indiatimes.com/industry/transportation/railways/punctuality-of-mail-and-express-trains-drops-now-one-in-every-four-trains-running-late/articleshow/102936795.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

7. https://government.economictimes.indiatimes.com/news/technology/quantum-computing-data-analytics-ai-to-transform- indian-railways-union-minister-ashwini-vaishnaw/98530077#:~:text=The%20Indian%20Railways%20is%20using,improve%20the%20railway%20signaling%20system

8. https://indiaai.gov.in/ministries/ministry-of-railways

9. https://indianexpress.com/article/explained/everyday-explainers/what-railways-ai-based-project-shorten-ticket-wait-lists-8404565/

10. https://medium.com/@ahmed.khursheed/application-of-data-science-in-indian-railways-problems-d74bba389e1c

11. https://readwrite.com/the-penetration-of-artificial-intelligence-in-indian-railways/

12. https://www.deccanherald.com/india/indian-railways-to-use-artificial-intelligence-data-analytics-to-improve-efficiency-926899.html

13. https://www.financialexpress.com/business/railways-indian-railways-to-adopt-artificial-intelligence-and-quantum-computing-technology-for-its-rapid-transformation-2999457/

14. https://www.globalrailwayreview.com/article/78696/ai-chatbot-bias-accountability/

15. https://www.hindustantimes.com/india-news/railways-to-implement-artificial-intelligence-data-analytics-for-better-operational-efficiency/story-iyMP1Yh5WyZKSP05dj8qOM.html

16. https://www.livemint.com/Opinion/Q8b7xXqCWssDtpjn1zFHiI/Why-the-Indian-Railways-will-face-an-AI-conundrum.html

17. https://www.quytech.com/blog/ai-in-railway-industry/#:~:text=Artificial%20Intelligence%20in%20the%20Railway%20Industry,-For%20the%20railway&text=The%20task%20is%20difficult%20due,the%20involvement%20of%20human%20factors

18. https://www.researchgate.net/publication/356665216_Artificial_Intelligence_in_Railway_Transport_Taxonomy_Regulations_and_Applications

19. https://www.statista.com/statistics/1029503/india-train-accident-number/#:~:text=The%20number%20of%20train%20accidents,infrastructure%20developments%20and%20technological%20advancements.https://www.timesnownews.com/technology-science/indian-railways-to-start-using-artificial-intelligence-quantum-computing-for-its-mega-transformation-across-india-article-98517929

20. https://zeenews.india.com/railways/indian-railways-to-use-ai-to-prevent-elephant-collisions-nfr-signs-mou-with-railtel-2586603.html