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Harnessing Artificial Intelligence for Enhancing Passenger Experience in Pakistan Railways: A Service Science Perspective

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ABSTRACT

The present research seeks to investigate the potential of Artificial Intelligence (AI) in improving the Pakistan Railways (PR) passenger experience in terms of operational efficiency, safety, and service quality. Pakistan Railways has been plagued by ongoing issues of delays, ticket shortage, safety issues, and all these factors decrease passenger satisfaction. Global evidence is available that daily services can be enhanced with AI in predictive maintenance, scheduling, safety, and customer-focused services. Qualitative conceptual research design was used, making use of literature review and secondary data analysis to put forward a framework for integrating AI in PR. The results indicate that AI applications enhance predictive maintenance, decrease delays, streamline scheduling, increase safety, and offer personalized passenger services. These results as a whole enhance satisfaction, loyalty, and efficiency. PR must adopt AI through phased pilot projects, enhance technical capacity, undertake stakeholder engagement, and obtain long-term funding for sustainable integration.

| Keywords: | Artificial Intelligence (AI), Pakistan Railways (PR), Passenger experience and Value co-creation |

Introduction

Pakistan railways (PR) is one of the most efficient and significant mode of transport that played a very prominent role in linking various parts of the country and catering for millions of passengers every year. PR has also had its share of many operational challenges over the years such as substandard infractions, poor organizational efficiency, many delays, and insecurity. These issues have affected the passenger experience and thus; reduced ridership (Khan, 2020; Ahmed & Ali, 2019). AI injects fresh vitality into digital businesses and facilitates the development of smart services to promote digital transformation (Bucsky, 2020; Khan, 2024). AI applications in transportation have shown significant promise in improving operational efficiency, enhancing safety measures, and providing personalized passenger services (Railway Gazette., 2020; Bucsky, 2020; El-Medany et al., 2021). AI integration is an opportunity to overcome these trends and improve the general passengers' experience. The integration of AI-driven applications must be accompanied by a thorough understanding of the passengers' needs, preferences, and pain points (Abduljabbar et al., 2019). AI technologies can be embraced in the different transport sectors across the world to come up with the best solutions which enhances operations' efficiency, safety, and customers' satisfaction. Pervasive range of AI implementation in the Railway system includes Predictive Maintenance, Automated Scheduling, Consumer Experience Enhancement, and Security & Anti-Terrorism Measures.

To organize the discussions systematically as regards the research questions and objectives of this paper, the following sections have been developed. Subsequently, the Literature Review section of this thesis aims to discuss previous studies on the implementation of AI in transportation and integrating theories of service science to improve passengers' journey. This part is dubbed Methodology and the part describes the

conceptual research design and the approach used while proposing the mentioned framework. The Key Areas for AI and Implementation of AI in PR section focuses on the components and procedures of the AI integration in the PR field. The last section, Results and Discussion, analyzes the advantages and possible difficulties of implementing AI in the context of the study and the paper's Conclusion provides the summary of the results and the directions for the further research and application of the findings.

This paper demonstrates that Pakistan Railways has faced a litany of perennial issues that presently prevent the organization from delivering a favorable passenger service. Measures can be grouped into three main factors that include operational, infrastructural, and safety problems. Inefficiencies in the operations of the public relations mainly present themselves in the form of frequent delays, suboptimal scheduling and even management of the available resources. At times, they attributed to old signaling, clerical operation, and the lack of proper maintenance of rolling stocks (Iqbal et al., 2018). Such inefficiency implies long waiting time and unpredictability for the passengers, factors that have negative impacts on their trip. The foundation of PR is quite primitive and requires radical improvements in terms of modernization. Some of the tracks, bridges, and stations have remained dilapidated; most of them have not been renovated, maintained, or upgraded resulting in reliability and security concerns (Rizwan et al., 2019). The absence of amenities that are associated with modern station also deters from passenger experience and comfort while traveling hence discourage the usage of the current stations. Practicality is another aspect of concern for the passengers of PR which is safety. There have been cases of derailment and collision and this has led to many questions being raised concerning the safety precaution or the measures that have been set in place (Shahbaz & Naeem, 2020). Another factor is also the absence of modern surveillance video systems that are vital especially in the aspects of crime and acts of vandalism. Today, AI provides a number of solutions that can be applied to the challenges faced by the PR, which will further increase the level of passengers' satisfaction by making the processes more efficient, safe, and personalized. Cognitive analysis of trens is one of the most significant trends of AI usage in railways with the prominent focus on the predictive maintenance. The application of AIs can be to decipher data collected by various sensors on trains and tracks to indicate failing and timely maintenance. This enables preventive maintenance hence lowering down the possibilities of bodily harm or project hold up (Ghosh & Chowdhury 2019). It can also be seen that the effectiveness of scheduled train services, which is critical for passengers, can be boosted substantially through the introduction of predictive maintenance. AI in planning and scheduling can provide solutions on the best time to schedule events and resources for the occurrence of these events by using past data and current conditions. This helps in enhancing the train frequency to be optimal, reduction of conflicts and efficient distribution of resources (Wang et al., 2021). Scheduling has to be automated so as to eliminate instances of delay hence making the running of trains smoother for this will be of benefit to the passengers. The use of AI in managing passengers entails timely information provisioning, travel customized recommendations and timely promotions depending on passengers' behavior patterns. Online analytical processing of passengers' data can be used by machine learning algorithms to offer specific services enhancing passenger's comfort (Goumagias et al., 2019). For example, AI is capable of recommending the best routes to travel, inform people of a delay, and give them discount for the most used routes. Underlying the role of AI in improvement of safety and security within PR, the automated surveillance and monitoring systems are crucial. Close monitoring in real-time using computer vision and machine learning techniques of suspicious activities, potential hazards and even maintenance troubles can be easily identified (Zhou et al., 2020). These systems can also be used to measure density of the crowd and control the passenger traffic to lessen chances of mishaps and enhancing the total security condition. Thus, the service science perspective can be used to get more comprehension and increase optimization of the AI application in the processes of the PR field. Service science is an academic discipline, which explicitly deals with the creation of service systems and development of service industries and focuses on

the process of recombination of services for the suppliers and consumers (Maglio & Spohrer, 2008). This perspective might be immensely useful for analysis of the PR aspect of AI because it underscores the necessity to anticipate passengers' requirements and how AI services can augment the overall experience.

In the sphere of PR, the co-production of value implies a direct interaction with passengers and integration of their perspectives into the services provided. AI can help do this through the provision of customized services as well as quarries for feedback as a means to improve from the passengers (interviewed in the Chase & Apte, 2007). For instance, AI-based chatbots can engage the passengers, offer help at every step and gather crucial insights related to passengers' experience. Service science underlines the factors of service quality and service delivery. AI can enhance both by cutting the time taken and eliminating the bottlenecks between processes while offering services that suit the passengers' needs (Spohrer & Maglio, 2010). The identification of ways in which PR can be of benefit to a transport entity suggests that by improving service quality and efficiency, the satisfaction level of the passengers is likely to go up thereby increasing loyalty and therefore the number of riders as well as the generated revenue.

Applying the AI technologies in the PR can improve its operational delivery, safety, and offering of services to the passengers progressively. This work presents a clear structure of integrating AI in PR and contains useful conclusions and best practices for its policymakers, railway managers, and technological suppliers. In this way, the proposed concept of co-created value and orientation to the quality and efficiency of performed services, as well as the highly developed organization of the PR's transportation system will become the modern Passenger Railways as the friendly transport system for all passengers in other developing countries.

Literature Review

The literature review focused on establishing a clear understanding of prior studies regarding the adoption of AI in transporting industries with a focus on railways. This involved addressing the theoretical evolutionary concept of service science and the rationale of applying the science to improve the passengers' experiences. Moreover, while reviewing the current and prior research on AI in railways across the world, the author also explained the prospects and issues in AI adoption in Pakistan Railways (PR).

AI in Transportation

AI technologies are being explored and adopted in the fields of transport; for instance, with regards to railways, aviation, and road transport. Such technologies as machine learning, predictive analytics, computer vision, and natural language processing have shown promising results in enhancing productivity, safety, and customers' satisfaction.

Predictive Maintenance

Predictive maintenance is one of the most intensively researched use cases of AI in transportation. It includes predictive analysis of data that has been collected from sensors and other devices, to forecast breakdowns or service requirements of equipment. By doing this one can avoid breakdowns on them, properly schedule the time to be used, and extend the useful life of the assets on hand (Ghosh & Chowdhury, 2019). In regard to the specificity of railways, it is pivotal to note that PM can be applied to many items such as tracks, trains, and signals.

In the research study of P.Ghosh and T. Chowdhury (2019) effective demonstration on how the phenomena of predictive maintenance brought benefits to railway transportation particularly to Indian Railways. In their study, they were able to find out that

the perks of AI-based PM with predictive characteristics are beneficial not just for lessening the frequency of equipment's malfunction but also in the enhancement of reliability. Similarly, in Wang et al. (2021) study of the Beijing Metro, AI was identified to have a future in the use of maintenance predicted through the study that showed reduced costs of maintenance, and higher quality of service was achieved.

Automated Schedule and Resource Planning

They have also adopted AI in the timetable of the transport systems as well as the management of the resources. Therefore, with the aid of AI algorithms for working out historical records, current status, and demand, the automated scheduling systems are capable of portraying the best schedule for specific trains alongside the resource distribution (Wang et al. , 2021). This is can lead to better operations, reduced cases of wastage of time among other advantages concerning the use of resources.

For example, Ferreira et al. (2020) reveal that the implementation of AI-based scheduling systems led to improved punctuality in Lisbon Metro as well as reducing the operational expenses. Based on the research done in this paper, it is concluded that AI provided an approach to an adaptive schedule that would fit into operation as and when the reality sets in by ensuring there is a maximization of the number of train sets to avoid conflicts. As for the Tokyo Metro, Zhang et al. (2019) also provided evidence on how AI facilitates resource anywhere in a way that enhances efficiency and users' satisfaction.

Personalized Passenger Services

One more area of application of AI in transport is that of offering individual passenger services. Passengers' real-time data and information fed into the AI algorithms offer solutions that entail travel advice, offers as well as changes among others as indicated in the study by Goumagias et al. (2019). This can improve the awareness of the traveller through making his/her travel more convenient, efficient and fulfilling.

Goumagias et al. (2019) also studied the use of AI for travel recommendation on the basis of the history of travel data collected by different modes of transport in Europe. This research also showed that segmentation of services created enhanced satisfaction and loyalty of the passengers. Consequently, Chen et al. (2020) in the case of AI adoption in Beijing Metro noted that offers like travel information and promotional material delivered to the passengers' mobile devices boost satisfaction and spending.

Enhanced Safety and Security

This in particular means that conversing transportation processes AI technologies can also improve safety and security by applying superior surveillance and monitoring means. By use of apt Computer vision and machine learning algorithms, activities, potential hazards, and problems such as maintenance ones can be noticed immediately and authorities in charge informed (Zhou et al., 2020). They are also used to control crowd densities and passenger traffic flow; thus, such systems can minimize accidents and enhance security.

As Zhou et al. (2020) showed works in a separate research regarding the use of AI in managing the safety and security of Shanghai Metro. To the specific issues of the analyzed metro system, the study showed AI systems' positive influences: crime and vandalism occurrence significantly decreased and security was enhanced. Alike, Lemos et al. (2019) study on the Implementation of

AI technologies in the São Paulo Metro shed light on the strengths of AI in crowd density tracking and passengers' movement control all in an aim of enhancing safety and begetting unhampered flow of people.

Service Science Perspective

Defined as a branch of science that deals with the creation of services and the management of the process through which such services are delivered, especially with focus on the processes through which organizations and customers collaboratively produce value (Maglio & Spohrer, 2008). This perspective is useful for helping to explain the role of AI technologies in enhancing the clients' experience in transportation by increasing service quality.

Co-Creation of Value

The co-creation of value is the core of service science; it underscores engagement for the customers during the service designing and delivering processes (Chase & Apte, 2007). For example, in the vehicle transport, it entails identifying the passengers' requirements as well as request to create AI systems that complement the overall service provision.

Chase and Apte (2007) have also paid much attention to the management of value co-creation in service operations; they pointed out that customers should be involved into the process of services design as the way to reach better outcomes and increase of satisfaction. In the same vein, Spohrer and Maglio (2010) identified the support of technology as an element to fostering value co-creation; thus, AI can offer customized services, collect information, and refine service delivery as a result of passengers' feedbacks.

Service Quality and Efficiency

Availability of services and the service delivery are very vital in the operation of transport systems. Service science focuses on the development of appropriate services that would best fit the needs of the consumers while offering quality services and speed (Maglio & Spohrer, 2008). It can also help with enhancing both by integrating smart systems to eliminate bottlenecks, executing services that accommodate passengers' requirements.

A case of study by Fitzsimmons and Fitzsimmons (2011) brought out the significance of service quality in transport stating that enhanced service quality is likely to have a positive impact for enhanced customer satisfaction and loyalty. Likewise, Parasuraman et al., (1985) came up with the SERVQUAL model, which outlines a way of measuring the gaps of the perceived and expected service quality. The ordinary use of AI includes increased service quality resulting from the utilization of the real-time and personalized services, and effective operation.

International best practices of AI adoption in rail transport

It is worth mentioning that Indian Railways are one of the key adopters of AI technologies aiming at enhancing its functioning and passengers' satisfaction. While analyzing the use of AI Ghosh and Chowdhury (2019) shed light on the use of AI for predictive maintenance for Indian Railways. The investigation revealed that AI-based PM caused fewer cases of equipment breakdowns and increased the dependability of equipment. Also, the Indian Railways has employed the use of artificial intelligence through the incorporation of chat bots that assist guests in real time as well as through gathering the opinions of the guests.

Another Asian Metro is also leveraging AI technology to enhance the quality and standards of the Beijing Metro service delivery. Wang et al. (2021) described a study of the use of AI for prognostics and health management as well as scheduling in Beijing Metro. Based on the study, it was established that AI based predictive maintenance saves cost for maintenance and enhance the general service quality while AI based scheduling relieves train frequency and leaves out delays. Further, the Beijing is using the artificial intelligence in the surveillance systems to improve the safety and security levels and hence cut incidences of insecurity such as theft and vandalism.

Tokyo Metro was one of the first cases to embrace AI when it came to improving resource allocation and increasing the quality of service. Zhang et al. (2019) also pointed out at the usage of artificial intelligence in the context of resource management in the Tokyo Metro resulting in increased resource use efficiency and customers' satisfaction. Also, the Tokyo Metro has adopted the use of artificial intelligence in passenger services, for example, customized travel information and travel advertisements based on the passenger's usage history.

Potential Benefits of integrating AI in Pakistan Railways

This enhanced customer service can contribute to increased passenger loyalty and reduced operational costs for Pakistan Railways, as fewer staff may be required to handle routine inquiries and tasks (Ameen et al., 2021).

The use of AI in Pakistan Railways has several opportunities such as increasing organizational effectiveness and efficiency, increasing security and safety of passengers, and providing customers with highly customized services. It is possible to state that all these opportunities can improve the general passenger experience and solve the problems that have been emerged in PR for a long time.

Improved Operational Efficiency

The application of AI can bring about benefits in scheduling of appointments and PR resources and asset maintenance among others. By using scheduling systems that are reliant on Artificial Intelligence, it is possible to predict historical data and conditions, and passengers' demand on trains, hence, coming up with preferable time tables and resource allocation that will in the end reduce the much time being incurred by trains (Wang et al., 2021). This reduces the risk of equipment breakdown, which in turns guarantees punctual train services as opposed to breakdowns which is experienced in conventional maintenance processes (Ghosh & Chowdhury, 2019).

Enhanced Safety and Security

Several applications of AI technologies will be beneficial in magnifying safety and security aspects in PR, including surveillance and monitoring systems. By using Artificial Intelligent the surveillance system can generate alarms when there is any suspicious movement, risks or damages or any maintenance problem to enhance the security of the environment (Zhou et al., 2020). Moreover, the application of AI can also track the density of people and direct the passenger's movement to avoid every susceptible accident.

Personalized Passenger Services

AI can also be used in PR to offer specific customer solutions which make the experience better and easier (Berry et al., 2002). The passenger data can be analyzed through the AI algorithms in the system to alert the customers or recommend the services, real-time updates, or promotions (Goumagias et al., 2019). This can also increase the

satisfaction and loyalty of the passengers travelling because it becomes easier and more fun to travel.

Challenges of AI Integration in Pakistan Railways

As promising as the use of AI can be to the field of PR, there are several issues that need to be sorted out for efficient introduction of the new technology. Some of them are technical; others are financial, and there may be organizational challenges.

Technical Challenges

AI application in PR is complex and depends on the presence of technical support and qualified specialists. This includes the incorporation of sensors and other data capturing equipments, the design and the crafting of AI algorithms and incorporating AI into existing structures (Ghosh & Chowdhury, 2019; Khan & Alam, 2020; Ahmed et al., 2022). Besides, special attention should be paid to data privacy and protection, especially in case of passengers' data processing - data security is of paramount importance.

Financial Challenges

One of the factors that have been severally raised by writers as a major issue that continues to hinder PR from embracing the AI technologies is that of cost. This includes costs such as acquiring sensors and other equipment, programming the AI algorithms, and staff education (Wang et al., 2021). Secondly, costs which might arise from regular maintenance and enhancement of the AI systems will also contribute to the costs since they are a continuous process.

Organizational Challenges

Specifically, the work of AI in the PR paradigm would entail organizational change as well as the acquisition of new skills and competencies. This entails creating awareness to the human resource about use, upgrade and control of Artificial intelligence systems, creating new process, procedures and establishing culture and practices of improvement (Zhang et al., 2019).

Furthermore, change management of human resources for better implementation focuses on catering to stakeholder's resistance to change.

AI application in transportation, especially railways, has great prospects for increasing productivity and safety while enhancing the client's experience. The use of AI technologies in some of the areas like the predictive maintenance, automated scheduling, passenger services, and safety have also been illustrated in some of the case studies that have been implemented across the World. The application of a service science approach can also enhance the effectiveness of the interaction between the service delivery entities and passengers, hence improving the delivery of the services.

However, incorporation of AI in Pakistan Railways poses several issues that need to be dealt with in order to have efficient utilization of AI. This may work as technical, financial and organizational restraints. To overcome these challenges, it is thus necessary to work with efficient and innovate levers of growth, which imply the construction of realistic and global HR strategies, with different levers such as the construction of strong data privacy and security or improvement of skills and infrastructure, the promotion of company culture and business risk-taking.

With the help of the AI technologies and overcoming these challenges, Pakistan Railways may raise its operational productivity, safety, and security measures, and the

passenger services that may satisfy everyone in the train. This can cause greater satisfaction and loyalty and turn Pakistan Railways into a modern, passengers' friendly transport company.

Methodology

Material and Methods

To reveal the role of AI in improving passengers' experience in PR based on the service science perspective, this section was structured into the several parts; which include research design and methodology, data collection, data analysis and an evaluation of ethical issues.

Research Design

For this research, a conceptual research design was used since the aim of the paper included suggesting new models of how the different variables interrelate with each other, grounded on the current literature. The conceptual research design entails the identification of the various previous researches done on the area under study in order to form a coherent research synthesis. Through this approach, the researcher was able to locate areas of converging and diverging opinion about the subject, and the gaps that would warrant proposition of the framework for integration of AI in PR. Further, researcher tried to elaborate and prove how Generative Artificial Intelligence (AI), specifically, ChatGPT, can be helpful in its contribution to answering the question of how harnessing Artificial Intelligence can enhance the passenger experience of Pakistan railways within the realm of Service Science. Additionally, AI was further requested to answer a list of questions that were open-ended for the purpose of gaining a deeper understanding about a customer's experience perusing their role as a passenger with PR. Outcomes reflected in Table 1 as Annexure A.

Conceptual Framework Development

The conceptual framework for integrating AI in PR was developed through an iterative process of literature review and theoretical analysis. This encompassed identification of the AI studies in transport, theories of service science, and how AI has been implemented in railways. These findings were then integrated in an attempt to develop a conceptual framework to fit the research objectives and questions stated in this introduction.

Data Collection

As the methodology adopted in this study, the data collection was done using secondary research materials sourced from academic journals, industries reports, government publications and case study. The data collection process involved the following steps:

An initial review of the literature was done to identify papers and articles on the mater using academic search engines like Google Scholar, IEEE Xplore, and Science Direct among others. The search strings used in this research are 'AI in transportation', 'predictive maintenance', 'automated scheduling', 'personalization of passengers' services', 'railway safety', 'service science' and 'value co-creation' Some key features that defined the inclusion criteria include the relationship of the study to the research objectives; whether the study was published in a peer-reviewed journal or reputable industry report; and the publication year, which had to be Only those studies which complied with these aspects or those that targeted other issues were eliminated. Originally, data from the selected studies were developed and classified into relevant themes. This covers information on AI uses in

transport systems, concepts of service science and issues on the use of AI in railways, as well as benefits and risks expected from AI integration.

Review of Industry Reports and Government Publications

To consolidate information and perspectives on Pakistan Railways and AI in transportation, certain official records documenting Pakistan Railways and AI advances received attention. This also entails reports from independent groups, for instance, International Association of Public Transport (UITP), the World Bank, and Pakistan Railways.

Data Analysis

The process of analyzing data in this study was based on thematic analysis, which is defined as an approach to the identification, comprehension, and reporting of patterns within the data. The process of thematic analysis was done in the following manner; the first part entailed going through samples of collected data several times for purposes of acquaintanceship. This entails indicating impressions and ideas, which one may consider in relation to the research questions. The data was, therefore, systematically coded by describing and marking aspects deemed pertinent to the research issues. This presupposes underlining the parts of the text associated with

AI in transportation, and service science theories and railways. The content identified with the rail implementations of AI is underlined. The results of the analysis of the initial codes led to the creation of the following overarching themes: Research themes were considered depending on their relation to the research questions and objectives such as; predictive maintenance, Automated scheduling and timetable, Personalized passenger services, safety and security among the themes analyzed were the following; It is crucial to review and reflect on the themes previously identified to ensure that they represent the data and are unique from each other. This includes ensuring i. e., internal validity, that data is collected within the themes, and none is missed. All the themes well-articulated and labeled to underscore what they contain and their relation to the research questions. This includes explanation/definition of each theme and the relevance of these themes to the research. The last analysis that was done was to filter the results obtained from the thematic analysis and then come up with the concept for integrating AI in PR. This was achieved by incorporating findings from the literature review and theoretical analysis to formulate an ideal model that can solve the research objectives.

Ethical Considerations

It was found that ethical issues should be kept in mind when conducting research, especially when handling secondary data and proposing new frameworks for the application that will influence stakeholders. The following ethical considerations were addressed in this study:

Reliability and credibility of information obtained from secondary research studies is very important. This involves assessing the credibility of the sources and comparing the information where this is feasible. To ensure the validity and reliability of the results, the methodology applied in this study and all the steps followed were openly described so that they can be replicated by other scholars. This was done to include detailed descriptions of some of the procedures that were involved in data collection and analysis. According to the rules of academic integrity, the sources of data and literature cited in this work were properly cited and acknowledged, to avoid violating the creators' rights of the original work. The consequences of the suggested AI integration framework for PR were also discussed regarding passengers, employees, and other users. The study was to develop

recommendations that improve the general experience of the passengers as well as to deal with the operation organizational difficulties.

Proposed framework for AI Integration in PR

As such, it was possible to formulate a conceptual framework from the literature evaluation process and thematic analysis, which has pointed towards AI integration in Pakistan Railways. The framework includes the following key components:

Predictive Maintenance: Artificial intelligence-based prediction for the improvement of product reliability and minimum time out of service. This entails placing sensors on the trains and the tracks to capture data, and applying machine learning to determine from the captured data when the trains and track age might develop problems and fail.

Automated Scheduling and Resource Management: Smart scheduling technologies to help in the organization of the train timetables and the distribution of resources needed. This involves the use of past data as well as the current conditions in order to modify the schedules in order to achieve optimal working.

Personalized Passenger Services: AI solutions to give relevant travel information, the latest news feed, and promotional content. This entails the evaluation of various aspects of passengers for instance their expected tastes and providing personal services that would improve on their travel.

Enhanced Safety and Security: Integrating Artificial Intelligence that is used in surveillance and monitoring to enhance safety and Security. Some of these are the utilization of computer vision and machine learning algorithms to identify the occurrence of suspicious activities, existence of potential dangers, and any sign of possible breakdowns to authorities in real time.

Co-Creation of Value: Including the passengers during the choice, design and provision of the services so that AI advancement meets their needs and wants. This will involve the use of chatbots and feedback mechanisms in encouraging passengers to give feedback so as to enhance their experience.

This framework to adopt AI in PR addresses the current issues faced by PR that include operational inefficiency, train safety, and customers' satisfaction. The framework that was developed was supposed to utilize AI technologies in order to modernize and optimize PR as a realistic and client-oriented means of transportation. The outlined key components of the framework are predictive maintenance, automated scheduling and resource management, optimized passenger services, increased safety and security, as well as the co-production with the passengers.

Predictive Maintenance

Predictive maintenance is about the application of AI where data from a number of sensors and other sources can be used to flag potential equipment failures and maintenance requirements. This approach of maintenance goes a long way in avoiding breakdowns that are usually sudden, and the useful life of assets is also elongated.

Components of Predictive Maintenance

Data Collection: Various sensors fixed to the train, tracks, and other structures measure factors such as vibration, temperature, noise, etc.

Data Analysis: The gathered data are then fed to these algorithms which categorize it and make estimations of failure-related incidents. These algorithms can be trained from the records and past data of equipment failures and other maintenance activities.

Maintenance Scheduling: Following the predictions a number of maintenance activities are conducted beforehand to avoid failure to occur. This involves generalized preventive measures as well as measures for likely to fail components that would be plugged in at different times.

Implementation Steps

Sensor Installation: Fit smart sensors on the major subsystems of trains and structures to gather vital information in real time.

Data Integration: Design the big data system architecture for collecting data from sources such as sensors, maintenance history records, and operation logs.

Algorithm Development: Select, design and build machine learning models and introduce them to the context so that they can be trained to analyze the data and forecast the maintenance requirements.

Maintenance Planning: Create a system of maintaining equipment that is based on the forecasts, consequently, activates the maintenance process.

Monitoring and Evaluation: Sustainably improve the operation of the predictive maintenance system and update the algorithms as a result of new observations and input data.
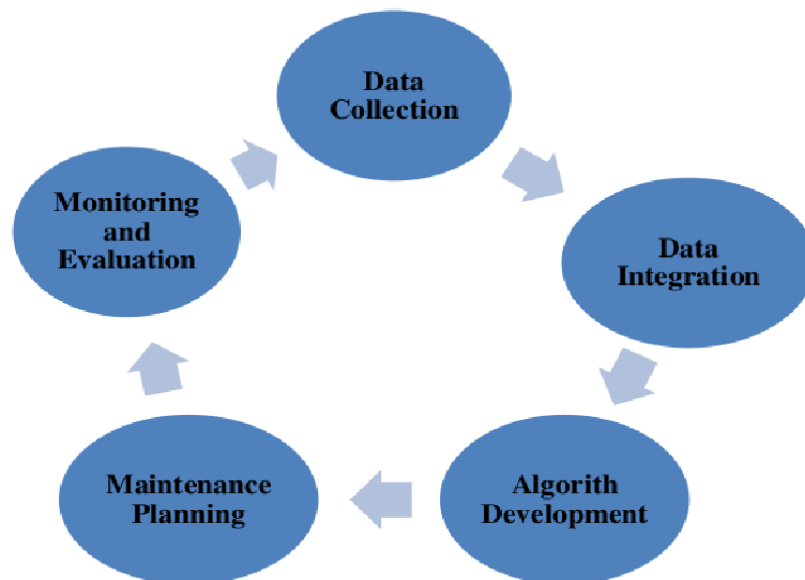

Figure 1: Flowchart of Predictive Maintenance Process

Automated Schedule & Resource Planning

Automated scheduling and resource management refer to the application of artificial intelligence in the train timetable that encompasses organizing the resource and the entire business procedures. This makes sure that we have the right train frequency, reduces contrasts, and enhances on the utilization of the available resources.

Components of Automated Scheduling

Historical Data Analysis: It also works with data based on train timetables, passengers' demands, and operational results of the train to recognize trends and patterns.

Real-Time Data Integration: Data obtainable in real-time include train position, passenger occupancy and operating conditions are fed into the scheduling information.

Optimization Algorithms: Sophisticated optimization techniques develop perfect train timing and resource management plans using the data of the past and real-time information.

Dynamic Adjustments: The scheduling system always contains the schedules and or resources within an organization and is sensitive to changes in passenger traffic and operational conditions.

Implementation Steps

Data Collection: Gather data related to train schedules, passengers' traffic, and organizational efficiency in the past.

Real-Time Data Integration: Implement a process for acquiring real-time information from different sources some of which are the train tracking system and the passenger counters.

Algorithm Development: Create solutions that will enable organization to get the best schedules and also the best plans for the usage of resources.

System Integration: Synchronize the scheduling system with existing operation systems in order to allow integration of changes.

Monitoring and Evaluation: The data continues to be collected and analyzed to assess the effectiveness of the scheduling system; the algorithms used will be updated with new data/insights
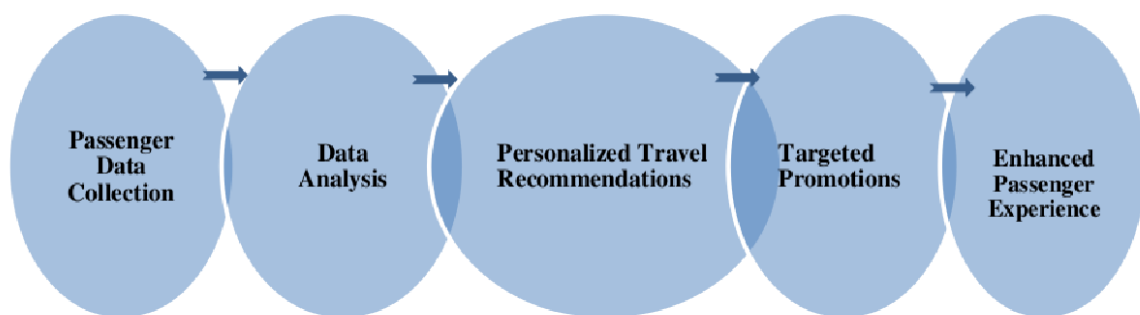

Figure 2: AI-Enhanced Scheduling System

Personalized Passenger Services

Public facing services refer to a situation where the passenger data is analyzed to create a customized message that informs the passenger, make recommendations, update and even promote value-added services. This has the effect of intensifying the value of the passenger journey through the provision of easier, faster, and more entertaining means of getting around.

Components of Personalized Services

Passenger Data Analysis: The AI systems use data on the customers' requirements and behavior, as well as their earlier movements to determine their requirements.

Personalized Recommendations: Accordingly, information about the most efficient routes and times is given for each passenger and, therefore, travel recommendations are developed for each passenger individually.

Real-Time Updates: Consumers use cable and other means of communication such as smartphone applications to access information on timetable including knowledge of any possible delays regarding the trains.

Targeted Promotions: Promotions and offers targeting customers are generated according to passengers' traveling experience and habits.

Implementation Steps

Data Collection: Passengers' preferences, habits, travel histories should be collected through surveys, using mobile applications, etc.

Data Analysis: Design a machine learning model as a part of big data processing to process the data collected and find out requirement and preferences of the passengers.

Recommendation System: Design a recommender system for giving suggestions of travelling to the passengers.

Communication Channels: Use mobile applications and SMS as possible means of keeping the consumers informed and notifying them about specific offers.

Monitoring and Evaluation: Check the efficiency of the personalized services in real-time and further adjusts the algorithms with the help of passengers' responses and newly gathered data.
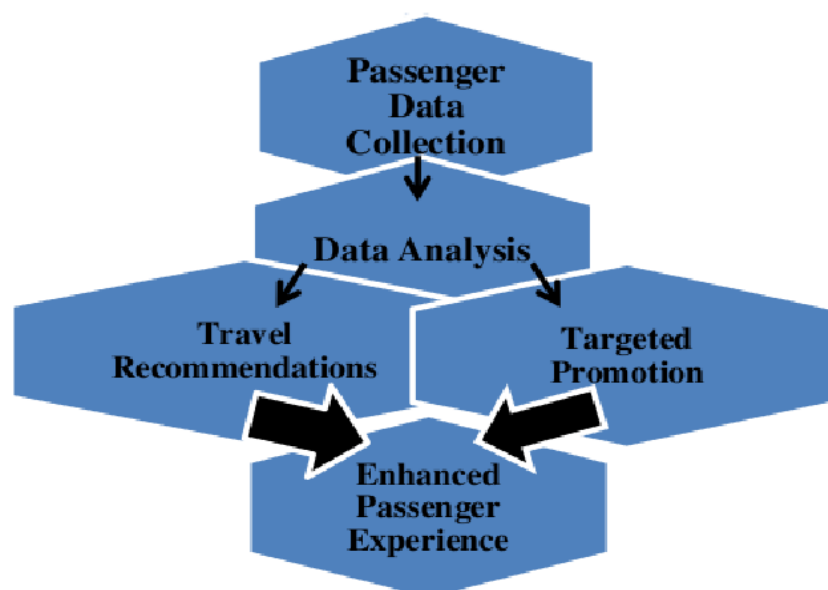
Figure 3 A Sample Conceptual Model in Support of Personalized Services

Enhanced Safety and Security

Technology deals with effectiveness of safety and security systems through the application of AI-based monitoring and surveillance in safety and security of PR. Such systems can monitor activities, and signal security forces, with regard to possible dangers or threats and faults that require repair, in real time.

Components of Enhanced Safety and Security

Surveillance Systems: The AI provides the surveillance systems which involve the use of computer vision and machine learning to work in real time over videos obtained from cameras on the trains and the stations.

Real-Time Alerts: The system produces alarms of any activity anomaly, possibilities of risks, and faults to the authorities in real-time.

Crowd Management: Machine learning recognizes information about passengers and crowd density to control people traffic and avoid overcrowding, which can help to avoid many sorts of mishaps and enhance safety at large.

Implementation Steps

Surveillance Infrastructure: It is recommended that security agencies should provide cameras and other surveillance devices on trains and stations to control passengers' behavior.

Data Integration: Design a core system for data acquisition of surveillance devices as well as other data acquisition points like passengers' flow counting system.

Algorithm Development: Calculate and apply for the machine learning algorithms to perform and analyze the collected data to identify the alarming activities, risks, and maintenance problems.

Alert System: Set up an alert system that generates alarms at any one time in situation of any trouble.

Crowd Management: The last measure should be to create and apply AI-generated analysis of potential crowding based on which it is possible to come up with consequent crowd management measures for the security of passengers.
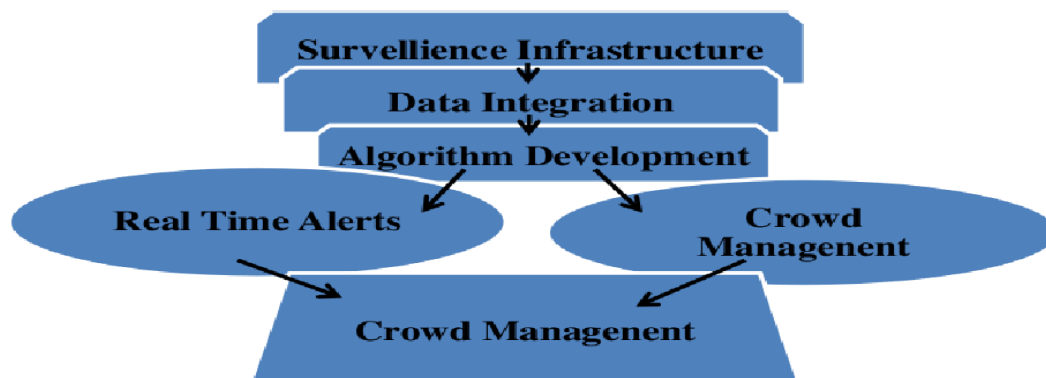
The relevant diagram is shown below:

Figure 4: AI-Powered Surveillance System

Co-Creation of Value with Passengers

Co-creation of value includes both the creation of value through the provision of

services and meaningful interaction with the customers, in this case, the passengers. This can be done through the following approach; AI can offer such services and at the same time collect feedback and improve on services given by the passengers.

Components of Co-Creation of Value

Passenger Feedback: Transforming a feedback system into an AI-powered chatbot helps gather actual-time evaluations and insights concerning the journeys.

Service Design: This paper explains how passenger feedback is employed in outlining and development of services to conform to passengers' needs.

Continuous Improvement: AI algorithms also help review the feedback received to decide about the course of action/s on how to improve the services even further.

Implementation Steps

Feedback Collection: Create and use machine learning-based customer service avatars and surveys to capture response from passengers in real time.

Data Analysis: These forms of feedback data should be analyzed using machine learning algorithms in order to find out the patterns of results as well as ideas for enhancing the results.

Service Design: It is essential to collect data regarding patients' satisfaction and usage of the service in order to better design and develop the services.

Implementation: Organize the provision of the newly developed or enhanced passenger services and closely assess the effect on the levels of passengers' satisfaction and experience.

Continuous Improvement: Concentrate on the dynamic enhancement of services depending on feedback and other data gathered in due course.
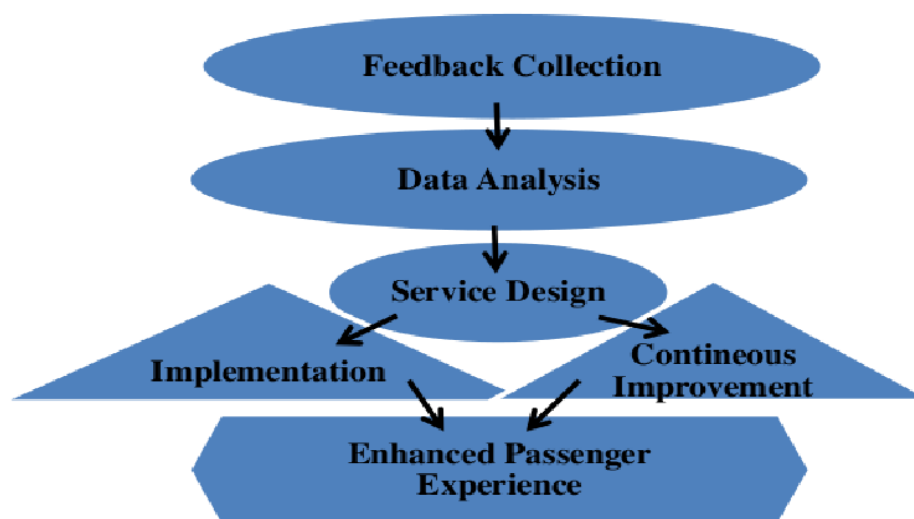

Figure 5: Co-Creation of Value Process

The outline plan for AI implementation in PR was intended to solve the problems of organizational functioning, risk minimization, and customers' satisfaction. With help of AI technologies in the framework of the predictive maintenance and scheduling, as well as understanding passengers' needs and preferences, ensuring passengers' safety and security, co-creation with passengers, PR can become a contemporary, effective, and customer-oriented transport complex. This framework offered a broad strategy on the application of AI in PR and recommendations for policymakers, railway authorities, and technology providers.

Results and Discussion

This section provides the results of the conceptual framework for AI application in PR and their implications, advantages, and opportunities alongside the risks and difficulties associated with the AI adoption in PR. The results are organized according to the key components of the proposed framework: These are, for instance, predictive maintenance, automated scheduling of activities and resources, tailored passengers' services, improving safety and security, and user-innovated solutions with passengers. Speaking of the railways, AI application can be used for predicting equipment failure, informing passengers in real-tome, making individual recommendations, and improving safety and security issues. Such innovations based on the use of artificial intelligence can contribute to the improvement of the railway transport system focusing on passengers (Candelieri et al., 2021).

Still, it is rather possible to state that applying the perspectives of AI, the efficiency of PR's operations can be improved through introducing the system of predictive maintenance. In this way, by foreseeing the equipment failures and maintenance requirements, PR can carry out a necessary maintenance endeavors before the occurrence of a significant number of break-downs and consequently, the service interruptions (Ghosh & Chowdhury, 2019; Wang et al., 2021). Reducing failure costs that arise from the stoppage of an organization's production process is another advantage of using predictive maintenance. The decrease in downtime also gives a proportional increase in productivity and cash flow (Ghosh & Chowdhury, 2019).

One of the advantages of AI systems is that using past performance and the current state of things; it is possible to adjust the train timetable properly. This leads to increased train productivity, time efficient, better system capacity and productive use of resources (Ferreira et al., 2020; Wang et al., 2021). Processing of schedules and resources in identifying time gaps also lessens the waiting time which improves the satisfaction level of the passengers (Zhang et al., 2019).

Planned services like as travel advisory, real time, and promotion services improve passenger's satisfaction. Travelers get information in their preferred language and in accordance with the their choice and concerns (Goumagias et al., 2019; Chen et al., 2020). Self-service technologies augment the customers' experience; therefore increase the overall patronage by minority customers. Goumagias et al., (2019) has elaborated the insight that where passengers get services respective to their likeliness in travelling, they will choose PR more when travelling.

Intelligent security systems improve security since they are able to identify any activity that violates public security and inform security agencies on the same in real-time. This brings down the rates of criminal and vandalism incidences thus enhancing safety for the passengers (Zhou et al., 2020). The automatic systems for the management of crowds and passenger traffic can cope with the increase in density and thus the likelihood of accidents and guarantee safe travel conditions. This is especially when travelling on congested routes as well as during the rush hours of the day and nights (Lemos, et al., 2019).

Incorporation of the passengers in the provision of services through feedback by stem-based systems encourages the customers/population. Consumers develop a feeling that they are of immense importance and thus become willing providers of criticism (David, 2014). The real-time compilation and examination of passengers' feedback also help PR to locate sectors that require improvement and apply changes to improve service quality and passengers' satisfaction (Spohrer & Maglio, 2010).

From the findings of this research it can be concluded that it is possible to achieve major performance enhancement in the Pakistan Railways operations, safe working environment for employees, and enhanced passenger satisfaction by adopting AI technologies into this organization. Nevertheless, the effective integration of AI into PR entails the consideration of several factors that are technical, financial, and organizational in nature.

Some of the benefits that could be obtained include; the efficient use of artificial intelligence to determine when maintenance checks are necessary would alleviate the time taken for the exercise and the scheduling of operations would also streamlined than it is now. This way, PR can prevent or, at the very least limit, a myriad of maintenance issues and train schedule mismanagement - all contributors to delays or service interruption in a railway system (Ghosh & Chowdhury, 2019; Ferreira et al., 2020). Individualized and extraordinary services for the passengers of the trains as well as measures of safety are crucial factors to a better travelling experience. Passengers are able to get information which is up to date, they get a convinced feeling that is safe to travel and they get a more comfortable ride. This can result in higher satisfaction levels, customer loyalty and the number of riders (Goumagias et al., 2019; Zhou et al., 2020).

The effective implementation of the strategies pertaining to predictive maintenance and optimum resource management can go a long way in sprucing up the overall cost saving potential of PR. The availability of the major equipment means lower maintenance cost and higher revenue is another implication of effective mitigations (Ghosh & Chowdhury, 2019; Zhang et al., 2019;   Gupta et al., 2019). Smart monitoring and crowd control methods increase security and safety for individuals and properties in PR and decrease the threat of accidents and criminal activity. Although it enhances the quality of services, pragmatic structure, and characteristics of the passenger's trip, it also provides PR a safer and more reliable mode of transportation (Zhou et al., 2020; Lemos et al., 2019).

AI technologies' application involves greater technical readiness and skill to integrate and maintain. These are installing sensors, AI algorithms' development, and incorporation of AI systems into the existing social structures. Maintaining confidentiality and security of the data is also essential when dealing with passengers' information is also vital (Ghosh & Chowdhury, 2019). One disadvantage of using AI technology is that it implies high first costs to integrate this sort of technologies into the organizations. This is done through buying sensors, integration of the sensors, designing of the AI algorithms and staff education. Also, it disclosed that the implementation of AI solutions also involves additional annual maintenance charges and updating of the system which requires further investment (Wang et al., 2021).

Amalgamation of change management and acquisition of new skills and capabilities are the key concepts in AI implementation. This means education of personnel in AI solutions, creation of new work processes and AI-related procedures, and creation and maintenance of the climate conducive to AI adoption and improvement. Stakeholder management also plays an important role in effective implementation since more often than not people resist changes that are being implemented (Zhang et al., 2019).

To address the challenges associated with AI integration in PR, several strategies can be implemented:

Capacity Building: Train the required workforce to obtain the skills and knowledge essential for applying knowledge representation in practice. This includes increasing awareness and knowledge of AI among the organization's personnel; as well as, the creation of new procedures and methods for AI implementation.

Stakeholder Engagement: Involve everybody that is affected by AI, including the employees, passengers, and policymakers, in the adoption of AI. This encompasses the communication of the positive impacts of AI and managing all the issues of change (Hicham et al., 2023).

Pilot Projects: Introduction of pilot projects before it is possible to test and develop the perfect Artificial Intelligence technologies for implementation on bigger scales. This makes it possible to come up with probable trouble spots to avoid and general information on how to achieve a proper implementation.

Collaboration with Technology Providers: Engage the technology providers to support their knowledge and tools for increasing the usage of AI. This also means incorporating with AI experts, sensory producers, and software design and developing firms to design and alien AI systems.

Sustained Investment: Pursue consistent long-term focus on the advancement of AI, especially technology and IT systems. This entails committing adequate provisions for the first push and subsequent upgrade and support.

Implications for Future Research

Consequently, the results derived from this study will act as a reference framework for further research activities with regard to the integration of the AI in railways especially in developing countries. Subsequent research can then extend itself towards conducting empirical studies to validate the development of the proposed framework as a theoretical model and as a means to measure the real difference made by the incorporation of AI in PR in terms of efficiency, security, and subjective experience among others. Existing surveys of AI applications in railways of different countries may be compared to ascertain common practices/precautions. Scholars might consider the new developments of the AI technologies that can complement the railway system, for example, self-driving trains, or refined predictive algorithms and models. They may look at how the introduction of the policy affects the position of artificial intelligence in railways, data protection, data security and ethical issues among others.

Therefore, the advancement of AI technologies in Pakistan Railways (PR) has the propensity to greatly transform necessary operational factors of productivity, safety and service. The paper presents a conceptual plan to integrate AI into PR and identifies problems that will need to be solved. It means that, on the basis of AI-driven predictive maintenance, effective scheduling, personalized passengers' services, increased safety and security, as well as the generation of the value with passengers' involvement, PR should be translated into a contemporary, effective, and Passengers' oriented transport system. Yet, overriding the methodical, fiscal, and structuring issues is pivotal to successful enactment. The outcomes of the current research will also be meaningful and useful for policymakers, railway managers and supervisors, and technology companies.

Conclusion and Recommendations

The use of AI technologies in Pakistan Railways is an area that has the potential of turning Pakistan Railways into a near modern railway system that aims at providing efficient and customer centric services to the travelling public. From the application of such advanced AI technologies as predictive maintenance, smart scheduling, passengers'

individualization, safety and security concerns as well as co-creation with passengers, PR can solve its prior issues and amplify its performance and convenient services for passengers. Nevertheless, for the innovation of AI in PR, some technical, financial and organizational issues have to be solved. To cultivate the AI experience to its complete, core components include strategic planning, building up specific capacities, engaging all potential stakeholders, undertaking pilot projects, partnering with technology vendors, continual emphasis on investment, and more. The proposed framework and the research results presented in this study give ideas and suggestions that could be helpful to the policymakers, the railway authorities, and technology suppliers. Future studies should be directed towards, developing and testing AI, comparing the outcomes, technological advancement, legislation and impact on economy to enhance the grasp and usability of AI systems in railways. In its endeavor to use the AI technologies and solve the problems accompanying it, the Pakistan Railways can be a role model to innovate the railway systems in the developing world to have better safety, efficiency and passenger friendly environment.

It is suggested that Pakistan Railways follow a phased implementation of AI, with pilot projects in high-priority fields like predictive maintenance and smart scheduling to start with. Technical capacity development and specialized workforce training must be done to facilitate smooth implementation. Financial sustainability must be ensured through regular investment and partnership with technology providers. Simultaneously, strategies for organizational change management need to be initiated to minimize resistance and cultivate an enhanced culture of innovation. Above all, engaging passengers through feedback systems and value co-creation will make AI-based solutions pragmatic, easy to use, and aligned with their expectations. This integration of technological, financial, organizational, and customer-focused measures will make Pakistan Railways a modern, efficient, and passenger-friendly transport system.

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