IoT Mechanisms Detecting Loading of Goods: A Review

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Abstract - *This comprehensive review paper delves into the intricate realm of coal transportation, specifically focusing on the development of an innovative IoT-based mechanism to meticulously detect and prevent underloading and overloading instances in railway wagons. As Coal India Limited (CIL) faces substantial financial implications from manual and contractual coal loading methods, the paper synthesizes insights from diverse research domains, including automated weighing systems, coal handling practices, railway track deformation studies, and soil foundation dynamics. The proposed solution involves the installation of load cells on each coal wagon, creating a sophisticated IoT network that seamlessly transfers real-time weight data to a centralized monitoring system through strategically positioned sensors. This comprehensive strategy not only addresses the immediate challenges faced by CIL but also envisions a transformative shift towards accuracy, efficiency, and accountability in coal-loading processes.*

***Key Words*: Internet-of-Things, Coal. Railway, Logistics, Digital Solution**

1.INTRODUCTION

For Coal India Limited, the complex process of transporting coal—especially the loading of railroad wagons—has demonstrated to be an ongoing obstacle. The common contractual and manual methods have resulted in underloading idle freight credits and overloading penalties, which have caused financial losses. This review paper explores a novel resolution predicated on state-of-the-art IoT technologies to address these issues. The paper presents a forward-looking mechanism by combining results from studies on automated weighing systems, thorough coal handling procedures, detailed analyses of railway track deformation, and predictive soil foundation dynamics. The clever placement of load cells on each coal wagon, which creates a complex Internet of Things network, is its fundamental component. This network makes it able to communicate weight data in the moment to centralized monitor by intricately connecting the necessary sensors. The primary goal is to bring about a radical alteration in the coal wagon loading industry by implementing a highly accountable and technologically advanced system.

2. LITERATURE REVIEW

The review of literature compiled from the available research papers covers a variety of topics, including automated systems for weighing and packaging, coal handling and dispatch plans, railway track deformation analysis, and the dynamic behaviour of soil foundations in heavy haul railways. These papers provide insightful information about technologies and development approaches that are pertinent to the development of a connected world for identifying overloading and underloading in coal wagons, in line with the particular problem statement that Coal India Limited (CIL) is facing.

Studies from 1978 to 1999

Ballast behaviour is evaluated using triaxial samples as a method of examining the deformation of railway tracks under various stress conditions. Furthermore to highlighting the interaction of factors influencing permanent deformation, highlights were the significance of comprehending ballast deformation for efficient track maintenance [1]Research like "Investigating Strength and Deformation Characteristics" highlight how crucial it is to understand the cyclic-stress levels of embankment materials since They provide crucial details about the variables affecting instability and settlement in heavy-haul railroads. The necessity of thorough testing procedures is emphasised in the article, which is consistent with the accuracy needed in coal transportation to avoid overloading and underloading. The making of a parametric capacity model by Canadian National Railway (CN) is emphasising the significance of it of efficient track asset utilisation. The study provides a framework that is consistent with the goals of optimising coal waggon loading in railway sidings By emphasizing the practical, theoretical, used, and available track capacity[2].

Studies from 2011 to 2015

Furthermore, exploring the geotechnical characteristics of ballasted tracks, highlights were the significance of substructure efficiency. This is consistent with the requirement for a strong system to guarantee precise coal waggon monitoring and weighing [3]. The WIM system could be considered both a diagnostic and prognostic tool very useful for predictive maintenance of the structural components of the vehicle [4].

Studies from 2013 to 2015

The creation of a precise, economical, and efficient microcontroller-based weighing scale. A PIC microcontroller, which has features like a RISC processor architecture and single-word instructions, is used in the scale. In comparison to microprocessor-based systems, the scale seeks to offer high accuracy and user-friendly functions at a cheaper cost. The microcontroller, PIC16F690, includes three different types of memory and eighteen general-purpose I/O pins. The experiment's findings demonstrate how voltage variations affect the weight values that are presented. In comparison to previous microprocessor-based weighing scales, the scale utilizes less components [5]. Among the most significant areas of research in the ever-changing railway industry is the integration of wireless sensor networks (WSNs) for condition monitoring. Various uses of WSNs in railway industry infrastructure, structure, and machinery monitoring. The investigation of transmission methods, network topology, and sensor design offers a thorough picture of the technical foundations of efficient condition monitoring. The literature review covers the various fields in which WSNs have shown to be useful, not just the railway sector. A paradigm shift in conventional monitoring techniques is indicated by the emphasis on autonomous data acquisition, continuous and near real-time data acquisition, and the application of data analytics. Energy-related problems are traversed by researchers, who offer creative fixes like ambient energy harvesting and alternative power sources. This comprehensive review provides a comprehensive perspective of the potential of WSNs in railway condition monitoring by synthesising findings from multiple studies. The analysis of fixed and movable monitoring systems, covering structures like bridges, tunnels, rail tracks, and track beds, further establishes the breadth of WSN applications. [6].

Studies from 2015 to 2017

The maintenance issues with ballasted railway tracks are examined and highlighting the effect of damp beds and fouling material on track performance. The study emphasises the significance of accurate measurement railway infrastructure maintenance, which is relevant to coal waggon loading even though it is not directly tied to IoT-based procedures [7]. Various dynamic weighing systems for rail freight transport are presented in, the implementation of dynamic weighing technologies, may be investigated for the purpose of creating an IoT-based coal waggon loading mechanism [8]. A load cell is a transducer that is accustomed to create an electrical signal whose magnitude is exactly proportionate to the force being measured [9].

Studies from 2017 to 2019

The implementation of mobile applications for farming, integration of monitoring systems, advanced decision support for farming, and the benefits of accurate measurements, time savings, flexible solutions, and effective data management in agriculture. [10]. By addressing important aspects of soil foundation dynamics, railway track behaviour, and coal handling, these papers collectively add to the body of literature. By incorporating study from these diverse domains, an Internet of Things (IoT) solution customised for CIL's requirements can be developed. This solution can help prevent underloading and overloading in railway wagons, which lowers costs and improves operational effectiveness. The prototype Weigh-in-Motion device was designed and tested using a motorbike operating normally as well as under load and at various speeds[11]. The stability of soil foundations under the dynamic loads of heavy haul traffic an overview of stability improvement tactics, such as protective layers, soil enhancement methods, and structural fixes, is presented, along with an analysis of degradation mechanisms [12].

Studies from 2019 to 2022

Transition zones in ballasted tracks highlight the significance of constitutive models, computational algorithms, and numerical analyses in predicting cumulative plastic deformation. The study highlights the dynamic difficulties that passing trains cause, which results in differential settlement. The incorporation of a Model of accumulated plastic strain in soil and finite-element analysis (FEA) creates a basis for comprehending the intricacies of dynamic loading, a notion that bears direct relevance to the dynamic coal loading environment in railway wagons. The study also presents an iterative process for forecasting differential settlement, This provides further information on the analysis of complex systems over time under different loads [13]. An automated weighing and packaging system with a microprocessor and pulse width modulation (PWM) is presented, with a focus on the proportionate relationship between vibrator speed and PWM duty cycle. This STM32F 103C6 microprocessor-based PWM-controlled system serves as the basis for investigating creative solutions in the literature that follows [14]. A weigh-in- motion method created for ballasted rails is presented and verified using fictitious data from Portuguese railway network trains [15].

3.INTERPRETATION AND FINDINGS

While reviewing the provided papers, a potential research gap can be identified under the framework of the specific problem statement related to the coal loading process in the Coal India Limited (CIL) railway sidings. The body of current research sheds light on various aspects of automated weighing systems, coal handling plants, railway track deformation, and soil foundation stability. However, the integration of these elements to address the underloading and overloading challenges in coal wagons at railway sidings seems to be a less-explored area.

3.1. Specific Focus on Coal Wagon Loading: None of the papers directly addresses the growth of an IoT-based solution for coal wagon loading. While there is substantial literature on dynamic weighing systems and railway engineering, a dedicated concentrate on the unique challenges and requirements of coal transportation through IoT-based mechanisms is lacking.

3.2. Integration of IoT with Dynamic Weighing Systems: There is one research gap in exploring how IoT technologies can be seamlessly integrated with such systems to monitor and control the loading process of coal wagons. The synergy between IoT and dynamic weighing systems needs further exploration.

3.3. Adaptation of Parametric Modelling for Coal Transportation: A parametric modelling approach for rail capacity planning. However, there's a gap in adapting this modelling approach specifically for coal transportation, considering the unique characteristics and challenges associated with loading coal wagons.

3.4. Geotechnical Considerations for Coal Wagon Loading: Insights for geotechnical considerations for ballasted tracks, There's not enough research. addressing how these considerations apply to the loading of coal wagons. Understanding the geotechnical implications of loading heavy coal wagons is crucial for the stability of railway infrastructure.

3.5. Validation of IoT-Based Solutions for Freight Transport: Evaluating the reliability and accuracy of IoT-based solutions for detecting overloading and underloading of rail wagons. There is one research gap in conducting comprehensive validation studies for IoT-based mechanisms in the context of freight transport.

3.6. Economic and Operational Impact Analysis for Coal Transportation: While the problem statement highlights the economic impact of underloading, there is a research gap in papers providing a thorough economic and operational impact analysis of implementing IoT-based mechanisms for coal transportation. Assessing the cost-effectiveness and operational efficiency of such systems is crucial for practical implementation.

3.7. Integrated IoT Solution: There is a gap in the literature regarding the development of a holistic IoT-based solution that seamlessly integrates sensors, data processing techniques, and control mechanisms to optimize and monitor coal loading in railway wagons.

3.8. Operational Feasibility: While the technical aspects of sensor technologies and automation are discussed, there is a gap in understanding the operational feasibility of implementing such a solution in a large-scale, dynamic environment like CIL's railway sidings.

3.9. Cost-Benefit Analysis: The literature does not thoroughly explore the cost-effectiveness and benefits of implementing an IoT-based solution for coal wagon loading, especially compared to

the expenses incurred due to underloading and overloading.

3.10. Real-time Monitoring and Control: The existing research lacks in-depth exploration of real-time monitoring and control mechanisms that can dynamically adjust the coal loading process based on varying conditions and requirements.

An extensive overview of wireless sensor networks (WSNs) in railway condition monitoring, covering various aspects from sensor design to network topology. However, a research gap becomes apparent in the limited talk about the cybersecurity challenges associated with the widespread deployment of WSNs in critical railway infrastructure. Given the sensitivity and criticality of railway systems, an in-depth exploration of potential vulnerabilities, security protocols, and countermeasures for WSNs is crucial.[6]

Another research gap lies in the requirement for more empirical research or case analyses showcasing the real-world implementation of WSNs in railway condition monitoring. While the paper provides a strong theoretical foundation, practical insights derived from successful or challenging implementations would enhance the applicability and reliability of the proposed WSN-based solutions. Additionally, exploring the cost-benefit analysis of deploying WSNs in railway monitoring systems possibly provide insightful information for stakeholders considering such implementations.

Filling up this research void would involve developing a tailored IoT-based a remedy that not only includes cutting-edge technologies but also considers the unique challenges and operational aspects of coal loading in the specific context of CIL's railway sidings. The identified research gap is the absence of a comprehensive and integrated solution that utilizes IoT-based mechanisms to detect and prevent underloading and overloading of coal wagons during the loading process at railway sidings. While individual components and technologies (such as automated weighing systems, vibration sensors, and microprocessor control) have been investigated in different contexts, There's not enough of literature that combines these technologies into a cohesive system tailored to the specific needs of coal loading in railway sidings.

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Table -3.1: List of sensors which are put to use in the study of weighing mechanism

Sr No	SENSORS	RESOURCES	APPLICATION
1	Hx711	[16]	A haptic tele-weight is a proposed gadget that will enable customers of virtual stores to feel an object's weight before making a purchase.
2	HC-SR04	[17]	Concerning the ultrasonic sensor to calculate the best reflections sound waves among the exterior surface of the shapes including the deviation of angles, then trying to find the best one through contrasting the error rate of each angle.
3	ESP8266-01	[18]	To educate people on some of the solved issues of the technology via a small Wi-Fi to serial module called ESP 8266
4	SD-Card Module	[19]	A system is put in place to keep an eye on the many parameters—such as temperature, voltage, current, and power factor—that are used by a machine to process a material in an industrial setting.
5	LCD Screen 16x2 I2C	[20]	16x2 LCD is used to give alert when reaching maximum temperature, time display and PWM percentage.
6	Micro-Controller Arduino Mega 2560	[21]	To implement IoT in accessing, controlling, supervising, and monitoring all actions that are typically associated with warehousing additionally increasing The effectiveness and security of those who do not have the authority to get entry to the room.
7	TOF10120	[22]	Estimate of obstacle distance was achieved with data fusion between Ultrasound and Laser sensor data. Among two sensors, Ultrasound sensor(HC-SR04) had better accuracy than Laser sensor(TOF10120) in experiments performed.
8	Node-MCU	[23]	ESP8266 Node-MCU features strong on-board processing and storage capabilities that enable it to be integrated with the sensor's particular devices via its GPIOs with the least amount of runtime loading and upfront programming.
9	Raspberry Pi 4	[24]	The Raspberry Pi4 embedded controller was utilized to design the home automation system. Wi-Fi technology was also employed to arrange and inspect the household appliances, enabling the user to remotely access the system from any location in the world.
10	Arduino UNO	[16]	Arduino UNO is an accurate platform for a series of lab settings. The tests reported presently indicate good reliability in controlling TTL length and delays both in the single channel and in four-channel experiments

4.FUTURE SCOPE

The future scope for the offered topic, "Development of IoT-Based Mechanism for Detecting Under and Overloading of Coal Wagons in Railway Sidings," is promising, with potential for efficiency, cost savings, and environmental effect enhancements. Several main topics may be investigated to improve and broaden the scope of this research:

4.1. IoT Integration with Advanced Dynamic Weighing Systems: Future study could focus on improving IoT technology integration with advanced dynamic weighing systems. This includes using real-time data transmission, edge computing, as well as machine learning methods to increase The precision and efficiency of coal wagon weight detection.

4.2. Sensor Technology Advancements: Advanced sensors designed specifically for coal transportation can be developed and integrated. Future systems could take advantage of future sensor technologies like enhanced load cells, 3D imaging, and advanced pressure sensors to provide more detailed and precise information on the loading process.

4.3. Predictive Maintenance and Analytics: IoT implementation can go beyond simple weight detection. To anticipate potential issues within the coal wagon loading process, future systems can incorporate predictive maintenance algorithms. Advanced analytics can be applied to enhance loading efficiency, decrease downtime, and boost overall operational performance.

4.4. Geotechnical Research for Stability and Safety: Additional research can delve into geotechnical considerations related to rail infrastructure stability and safety during coal wagon loading. Understanding how heavy loads affect tracks, embankments, and subgrades can lead to better engineering solutions that ensure both safety and efficiency.

4.5. Future studies: conduct cost-benefit analyses to assess the economic feasibility of implementing IoT-based mechanisms. For widespread adoption, evaluating the return on investment will be essential, taking into account things like lower penalties, increased operational efficiency, and lower infrastructure maintenance costs.

4.6. Global Implementation and Case Studies: Future research can focus on the global implementation of IoT-based solutions for coal wagon loading. Undertaking case studies across various geographic locations and taking into account varied operational scenarios will offer valuable perspectives on the technology's adaptability and scalability in a wider context.

4.7. Cybersecurity Measures: Strong cybersecurity measures should be emphasised in future research because of the integration of IoT. It is crucial to guarantee the security of data transmission as well as the Internet of Things infrastructure as a whole, particularly in vital sectors like coal transportation.

4.8. Remote Monitoring and Control: Examine the feasibility of controlling and monitoring remotely. Provide systems that enable remote modifications and real-time monitoring of coal loading operations, increasing productivity and decreasing The necessity of on-site assistance.

4.9. Scalability for Various Industries: Expand the developed mechanism's applicability to other industries with comparable weighing needs. The aim of research can be in order to create the system flexible and scalable to accommodate various material kinds, container sizes, and loading situations.

4.10. User-Friendly Interfaces: Make operator and stakeholder user interfaces better. The system's usability can be improved by creating dashboards and interfaces that are easy to use, allowing a larger range of users to access it without requiring intensive training.

4.11. Optimization and Scalability: Using historical data, current weather, and other pertinent variables, create sophisticated algorithms as well as machine intelligence models to optimize the coal loading process. Examine the IoT-based mechanism's scalability to fulfil the various capacities and operational requirements at various railway sidings.

4.12. Integration with Smart Infrastructure: Examine how IoT solutions can be combined with smart railway infrastructure to facilitate communication between loading equipment, centralized monitoring systems, and coal wagons.

4.13. Predictive maintenance: Use IoT data to implement predictive maintenance models to predict and prevent equipment failures, reducing downtime and maintenance costs.

4.14. Regulatory Compliance: Ensure developed solutions comply with existing rail regulations and explore opportunities to collaborate with regulators to improve industry standards.

4.15. Technological Innovations: Stay on top of cutting-edge technology like 5G, edge computing, and advanced sensing technologies that can further improve the functionality and performance of IoT-based systems.

4.16. Environmental Impact Assessment: Assess and minimize the environmental impact of IoT-based metrology systems. Consider elements like e-waste management, energy consumption, and environmental sustainability during the system lifecycle. Conduct investigation into the environmental impact of coal transport, including emissions and energy consumption, and explore opportunities to minimize carbon emissions through optimized loading processes.

By considering these aspects, future research scope can aid in the growth of smart, sustainable and technologically advanced coal transport practices in rail connections, benefiting both the industry and the environment.

5. CONCLUSION

To sum up, this thorough review paper delves deeply into the possibilities of an Internet of Things-based mechanism while navigating the complex terrain of coal transportation. Through the incorporation of knowledge from various research fields, the proposed solution not just takes care of the current issues that CIL is facing, but also paves the method by which a more advanced method of coal loading. Load cells installed on individual wagons, controlled by a complex IoT network and tracked in real time by cutting-edge sensors, represent a revolutionary step forward in accuracy, productivity, and responsibility. The suggested system has the the capacity to drastically alter coal transportation practices overall, additionally to its immediate financial advantages. This review paper's synthesis of a broad variety of literature offers a solid foundation for future developments in coal logistics as industries around the world struggle with the demands of accountability, sustainability, and operational optimization. In the future, the creation and application of this kind of Internet of Things-based mechanism has the capacity to transform not just the coal transportation industry but also act as a model for the wider advancement of intelligent, tech-driven freight logistics systems.

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