A System of IoT Devices to Prevent the Underloading and Overloading of Railway Wagons

Prof. Anilkumar Pathak[1], Kamlesh Kadu[2], Punam Patil[3], Kajal Sarbande[4], Sanika Mhaske[5]

[1]Assistant Professor, Dept. of Electrical Engineering, AVCOE, Sangamner, Maharashtra, India

[2,3,4,5]Students, Dept. of Electrical Engineering, AVCOE, Sangamner, Maharashtra, India

Abstract- Coal transportation poses substantial obstacles for corporations such as Coal India Limited (CIL), including concerns with route selection, rehandling, precise weighing, demurrage costs, and underloading fines. CIL's failure to adopt optimal transportation routes has resulted in needless costs. Coal rehandling at depots has proven expensive, and there are disparities in coal transportation rates. The lack of weighbridges makes accurate weighing difficult, resulting in probable pilferage. Demurrage costs have been a financial hardship, and railway carriages underloaded have resulted in fines. To address these challenges, the proposed IoT solution seeks to reduce financial losses, improve operational efficiency, increase accountability, ensure regulatory compliance, provide real-time monitoring, automate alerts and penalties, improve communication, improve data security, provide multilingual support, and, ultimately, increase revenue. This idea aims to change coal transportation by increasing efficiency, transparency, and cost-effectiveness for CIL and the government. However, it incurs initial expenses and complications associated with IoT deployment, maintenance, and regulatory compliance.

Keywords: CIL, IOT, efficiency, pilferage.

1. INTRODUCTION

Coal transportation provides substantial obstacles for organizations like Coal India Limited (CIL), such as route selection, rehandling, correct weighing, demurrage costs, and underloading penalties. CIL's failure to implement effective transportation routes has resulted in needless costs. Rehandling coal at depots has proven expensive, and disparities in coal transit rates have been found. The lack of weighbridges makes accurate weighing difficult, posing a risk of pilferage. Demurrage taxes have been a financial hardship, and railway wagon underloading has resulted in fines. To address these challenges, the proposed IoT solution seeks to reduce financial losses, improve operational efficiency, increase accountability, ensure regulatory compliance, provide real-time monitoring, automate alerts and penalties, improve communication, improve data security, provide multilingual support, and ultimately increase revenue. This invention aims to transform coal transportation by increasing efficiency, transparency, and cost-effectiveness for both CIL and the government. However, it comes with the initial expenses and challenges of IoT deployment, maintenance, and regulatory compliance.

An Internet of Things device system to stop railroad wagons from being overloaded or underloaded. The urgent need to improve efficiency and safety in the railway freight sector served as the impetus for this initiative. Railway wagons that are either overloaded or underloaded run the risk of mishaps, product damage, and interrupted operations. For many years, the railroad sector has relied on effective logistics to move cargo over great distances. However, there are difficulties in managing the loading of cargo into railway wagons, such as underloading or overloading, which can result in unsafe conditions, higher maintenance costs, and inefficiencies in operations. The incorporation of Internet of Things (IoT) devices into railway operations presents a viable solution to these problems.

Railway firms may enhance cargo loading procedures and guarantee the secure and effective transportation of goods by utilizing IoT technology, which facilitates real-time monitoring, data collection, and analysis. Because it makes it possible to carry people and products across great distances, the railway sector is essential to global transportation. A vital piece of infrastructure for many businesses, including industry, agriculture, retail, and logistics, is the railway network. In the railway industry, efficient cargo management is crucial to satisfying the increasing demand for freight transit while also guaranteeing safety and streamlining operations. This is a synopsis of the railway sector and the importance of cargo management.

Railways are still essential for the efficient and dependable transportation of commodities across long distances in the current transportation system. However, optimizing railway operations is still a never-ending task, especially when it comes to making sure that wagons are loaded evenly to avoid overloading and underloading. Conventional approaches to loading wagons frequently depend on manual effort and subjective estimate, which can be dangerous, inefficient, and cause harm to the cargo. The use of Internet of Things (IoT) technology offers a potential remedy for these problems. By utilizing IoT devices and data analytics, our technology, Smart Rail, revolutionizes the wagon loading process and ensures optimal capacity use while minimizing hazards and maximizing productivity.

Throughout the loading process, Smart Rail offers real-time monitoring and control capabilities by integrating sensors and communication modules into railroad carriages. Optimizing freight transportation operations requires effective railway wagon loading. In addition to causing inefficiencies, underloading and overloading both raise operational expenses and provide safety hazards. The objective of this project is to create an Internet of Things (IoT) system that will stop railroad wagons from being under or overloaded, guaranteeing maximum capacity utilization and improving efficiency and safety. Railroad networks cannot function properly without effective freight management. On the other hand, railroad wagon overloading and underloading can result in higher expenses, safety risks, and operational inefficiencies.

2. LITERATURE REVIEW

Coal is one of the most important basic energies of China. About 60% of the coal is concentrated in the western region of China like Shanxi, Shaanxi, and Inner Mongolia, but the coal consumption is relatively concentrated in the eastern provinces which with a developed economy, because of this, for a long time, China forms a basic pattern of " coal transportation from north to south " and "West coal east tune". Coal transportation mainly depends on the railway, highway, ocean shipping, and water transport. In coal transportation, the amount of railway transportation accounted for more than 60%, and in railway transportation, cola transportation accounted for about 40%. In recent years, despite the coal railway transport lines repeated expansion, the demand of the rapid increase of coal production and consumption cannot be satisfied.[1]

These researches mainly consider the coal transportation and import and export of coal from a view of unidirectional flow among regions, which is still the unidirectional supply and demand study even for the changes in sourcing and collecting features of coal resources. With a full view of the whole country, the route difference of coal flow hints at the different spatial distribution of influences and relations of the energy sources among regions, while the size of flow indicates the weakness or tightness of such relations. If only unidirectional flow is taken into consideration for the influences and relations of energy sources among regions, the interactive influence will be absent among regions. With two regions as an example, when Region A as the source of coal supply sends coal to Region B, it may as the collecting place receives the coal sent from Region B, namely Region A may take the feedback effect imposed by Region B. This energy flow of bi-directional features shows the particular interactive influence from one region to another. The closed flow of coal will not only go from a start place to one end but also the end will carry coal to the start, forming a ring flow passing through all the involved regions. The feedback flow may have a big or small size, reflecting the size of the feedback influence. The unidirectional flow can be held as a very small (as small as zero) and exceptional case of closed feedback flow as it lacks a route from the endpoint to the start. With a nationwide view, all the regions shall participate in such flow to undertake the true integration of research on the “whole system” (the country) and “single unit” (regions). If the research is limited to several provinces with a relatively frequent flow of coal but not expanded to the platform of all the regions, projecting the relations of all the regions, such research still is research on a separate “single unit”. Therefore, the closed coal flow ring does not only reflect the energy and economic relations of all the regions but also means an analysis from a systematic view.[5]

2030. The storage and transfer of coal amount in the Chongqing center is relatively small, but Chongqing has the combined transport advantages of railway and waterway. Therefore, not only the railway terminal facilities should be made full use of in the construction of the Chongqing center, but also the construction of combined transport facilities and the enterprises’ special line should be well done. The storage and transportation volume of the Wuhan center is minimal in the three logistics centers, which will not be conducive to the development and construction of a large coal storage and transportation base. However, due to its unique geographical and economic advantages, Wuhan Centre could combine the functions of distribution and circulation processing, and use advanced inventory management patterns. [6]

Due to the different cognitive structures, preferences, and interest motivations of each decision subject in coal mine accident emergency management, certain conflict is bound to occur in the decision-making action. Therefore, it can be considered that a “conflict-free cooperative game” is the essence of the game relationship between coal mining enterprises and local governments, because coal mining enterprises and local governments have different social attributes. Because of its social attributes, local governments should not only safeguard regional public interests but also safeguard the interests of organization members. However, in case of a conflict between the local government and the social public interest, some behaviors of leaders may cause damage to the social public interest because self-interest is the “natural” goal of the local government, that is, the government will have negative information integration behavior due to the high cost of integrating accident decision-making information. In the emergency disposal of coal mine accidents, coal mining enterprises, as the specific implementer, have sufficient resources with emergency information and technology, equipment and materials, emergency personnel, *etc.*, but they can also be regarded as profit-making organizations to undertake social responsibility while maximizing its interests is its main goal because of their obvious nature of “economic man”. When the social public interest coincides with the economic interest of coal mines, the government and coal mining enterprises will choose cooperation for the social public interest and positively respond. [7]

3. DESIGN METHODOLOGY

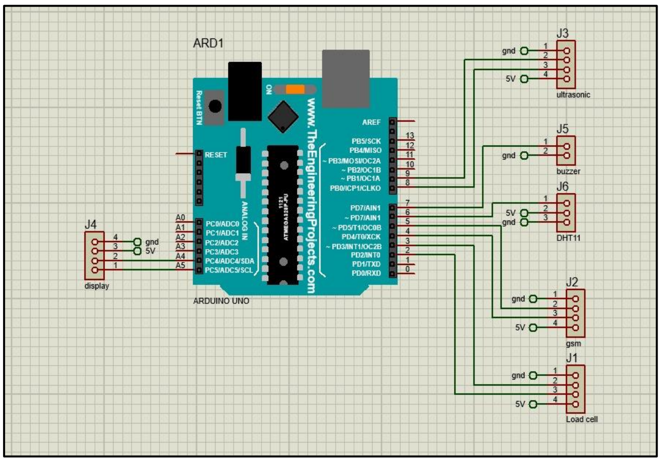

Fig1.**Block Diagram**

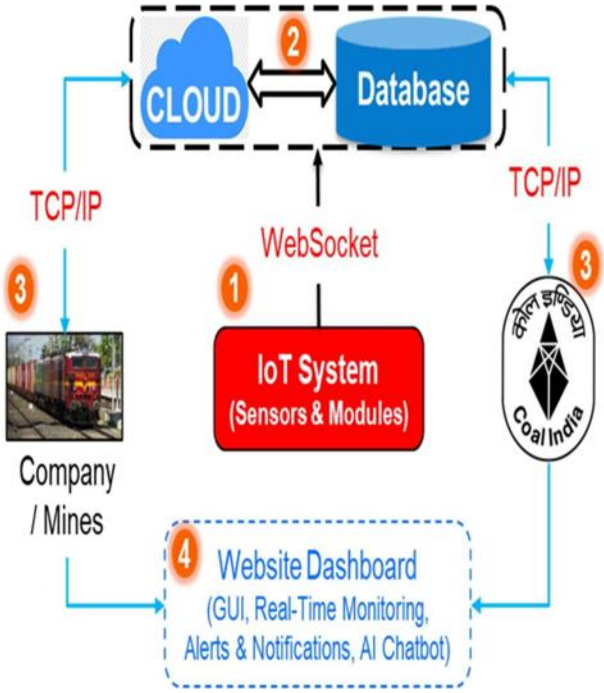

Fig 2. **System Architecture**

4. HARDWARE COMPONENTS AND SPECIFICATIONS

1. ESP32 Microcontroller

Fig3. **ESP32**

ntral processing unit of the IoT system. It plays a pivotal role in managing and coordinating data from various sensors and modules within the system. This microcontroller is chosen for its powerful capabilities, including built-in Wi-Fi and Bluetooth connectivity. It collects, processes, and transmits data to other components of the system, enabling real-time data analysis and display on a web dashboard and mobile application. It facilitates remote monitoring and control of the entire system ensuring that data is processed efficiently and decisions can be made in real-time.

2. SIM900A Quad Band GSM/GPRS Serial Modem

Fig 4. **SIM900A Quad Band GSM/GPRS Serial Modem**

The GSM SIM900A Module serves as the gateway to the internet, providing connectivity in areas with cellular network coverage. This module uses a cellular network to establish an internet connection, enabling data transmission and remote communication. In the context of the IoT system, the GSM module ensures constant connectivity to the internet. It allows for remote data communication, control, and the timely exchange of information with the web dashboard and mobile application. This connectivity is essential for real-time monitoring, alerting, and efficient management of the coal transportation process.

3. Compression Load Cell

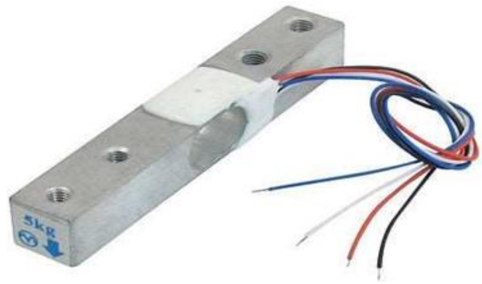

Fig5. **Compression Load Cell**

A Compression Load Cell is an essential component of the system, designed to measure the weight or load applied to it through compressive force. In the context of the railway wagons used for coal transportation, this load cell plays a crucial role in continuously monitoring the payload weight. When force is exerted on the load cell due to the loading of coal, it deforms slightly and produces an electrical signal proportional to the applied force. This data is then used to ensure that the coal loading remains within safe limits, preventing both underloading and overloading of railway wagons.

4. LCD Display 16*2

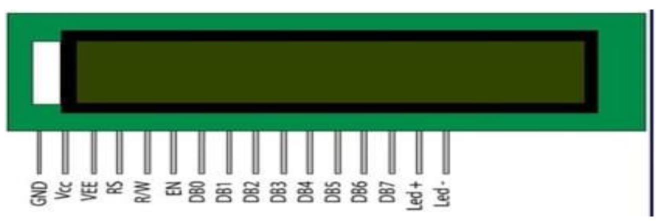

Fig6. **LCD Display 16*2**

We are using an LCD to display the Weight of coal loaded in the bogie. 16*2 LCD is named because it has 16 columns and 2 rows. It mainly operates on 4.7-5.3 volts. It uses liquid crystal to produce a visible image. It consists of 2 registers namely, command and data register. We use 4 data pins (D4-D7) it is connected to the controller pin (PB4-

PB7). These displays are preferred for multi-segment light-emitting diodes and seven segments.

5. Batteries

Fig7. **Batteries**

specifications and information about 12-volt batteries:
Voltage: A 12-volt lead-acid battery has a nominal voltage of 12 volts, but the actual voltage can range from about 10.5 volts to 14.5 volts, depending on the state of charge and other factors.
Capacity: The capacity of a lead-acid battery is measured in ampere-hours (Ah) and represents the amount of energy the battery can deliver over some time. The capacity of a 12-volt lead-acid battery can range from a few ampere-hours for small batteries used in motorcycles or lawn tractors to several hundred ampere-hours for large batteries used in backup power systems or RVs.
Chemistry: Lead-acid batteries use a combination of lead and sulfuric acid to store and deliver electrical energy. They are relatively inexpensive and have been used for over a century in various applications.
Charging: Lead-acid batteries must be charged with a compatible charger that is designed to provide the correct voltage and current. Overcharging or undercharging can damage the battery and reduce its lifespan.
Lifespan: The lifespan of a lead-acid battery depends on several factors, including the quality of the battery, the amount and frequency of use, the temperature and humidity of the environment, and the maintenance and charging practices. A well-maintained lead-acid battery can last for several years, while a poorly maintained battery may fail after only a few months.

5. FLOWCHART

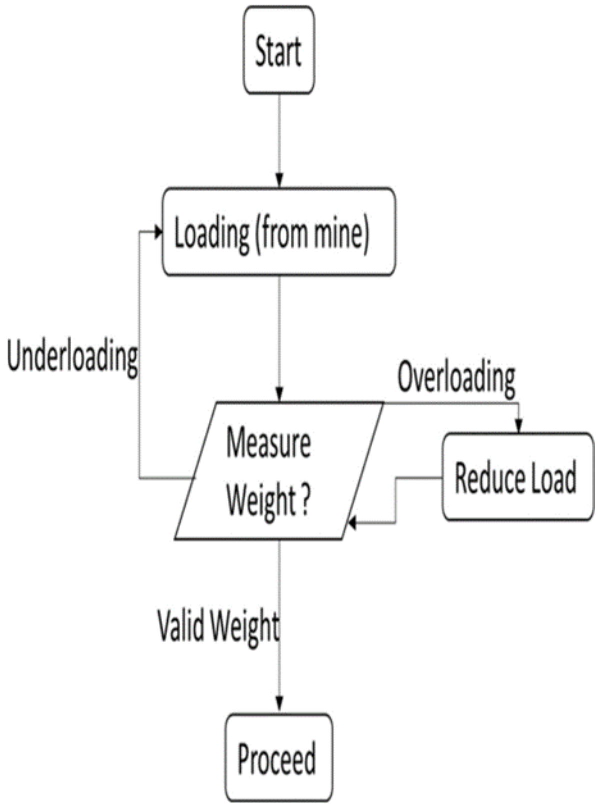

Fig 8. **Flowchart**

6. RESULT

The proposed idea aims to address the significant losses experienced by Coal India Limited (CIL) in the transportation of coal, specifically tackling the approximate 100% loss due to underloading and 25% loss due to overloading each year. The central component of this innovative solution is a prototype that integrates advanced technologies into the existing rail logistics system to ensure safe, efficient cargo transport.
At the core of this system is the Compression Load Sensor, installed between the bogie and the container of a train wagon. This sensor accurately measures the weight and payload of each wagon, thereby preventing both underloading and overloading. This real-time monitoring feature is essential for maintaining cargo integrity from the source to the destination, ensuring that coal transportation remains within specified capacity limits.
When an overweight or under-capacity condition is detected, the system triggers alerts. These alerts are transmitted to a central platform, accessible through a website and a mobile application. Automated penalties are enforced through this platform, discouraging deviations from the designated payload limits and promoting compliance with regulations. This mechanism not only enhances safety but also contributes to revenue generation for both the company and the government.
To further enhance the monitoring capabilities, additional sensors are integrated into the system. The CCS-3000Moisture Sensor measures coal moisture levels, while the IRU-3430 Series Ultrasonic Sensor continuously monitors the coal level in the wagon. These sensors provide critical data for optimizing cargo quality and quantity during transportation. Real-time tracking of trains and monitoring of speed are facilitated by the ZED-F9P-02B RTK GPS Module, ensuring the safe and efficient movement of coal. The ESP32 Microcontroller serves as the brain of the IoT system, responsible for monitoring all sensors and modules. It enables real-time data analysis through a user-friendly website dashboard and an Android application. Internet connectivity is established through the SIM900A GSM Module,

allowing remote data communication and control, which is essential for efficient logistics management.

7. OUTCOMES

1. **Cost Reduction:** Implementing IoT sensors and real-time monitoring can help minimize financial losses caused by underloading and overloading. By optimizing coal loading to the appropriate capacity, the company can avoid penalties and reduce unnecessary expenses, ultimately increasing profitability.
2. **Operational Efficiency:** The IoT system ensures that railway wagons are loaded to their capacity without exceeding safe limits. This optimization of coal transportation leads to more efficient operations, reduced rehandling of coal, and improved overall logistics.
3. **Transparency and Accountability:** By establishing a transparent system that enforces penalties for overloading purchasers, the company can eliminate the need to absorb costs associated with underloading through idle freight adjustments. This enhances accountability and encourages compliance with loading regulations.
4. **Compliance with Regulations:** The IoT system ensures adherence to railway rules and regulations regarding overloading and underloading. This helps in avoiding penalties imposed by railway authorities, which can be a significant financial burden.
5. **Real-Time Monitoring:** Implementing IoT sensors and technology allows for real-time monitoring of payload weight, moisture levels, and coal volume in railway wagons. This real-time data enables quick decision-making and proactive problem-solving.
6. **Automated Alerts and Penalties:** The system triggers automated alerts and penalties for instances of overloading or underloading, reducing the need for manual oversight and intervention. This automation ensures immediate actions are taken when violations occur.
7. **Improved Communication:** Seamless communication and data exchange between IoT devices, the central processing unit, and web dashboards or mobile applications enhance the management of the transportation process. It enables stakeholders to make informed decisions based on real-time data.
8. **Data Security:** The use of blockchain technology ensures the security of data and transaction records, preventing unauthorized access or tampering. This enhances the integrity of the data collected and stored by the IoT system.
9. **Customer Support and Multilingual Services:** The implementation of an AI-based chatbot for customer support offers 24/7 assistance, manages inquiries, and assists in emergency system management. Multilingual support enhances communication with a diverse customer base.
10. **Revenue Boost:** By reducing losses through penalties for underloading and overloading, enforcing penalties, and enhancing overall efficiency and transparency in coal transportation, the company can ultimately increase profitability for both itself and the government.

8. FUTURE SCOPES

The implementation of an IoT system to prevent the underloading and overloading of railway wagons carries significant importance for the efficiency, safety, and sustainability of freight transportation. Some key significance includes:

Enhanced Safety: By preventing underloading and overloading, the system reduces the risk of accidents, derailments, and damage to goods, ensuring the safety of railway operations and personnel.

Optimized Resource Utilization: Efficient utilization of wagon capacity leads to cost savings and increased profitability for railway operators by maximizing the volume of goods transported per journey.

Improved Operational Efficiency: Real-time monitoring and proactive alerting mechanisms enable operators to address loading anomalies promptly, minimizing delays and disruptions in freight transportation.

Revenue generation: It is a universal goal for businesses, and technology plays a pivotal role in achieving it. Digital marketing tools, e-commerce platforms, and data analytics are some of the applications used to boost sales and revenue. Additionally, subscription-based models and online advertising are revenue-generating methods employed by content creators and media companies.

Environmental Sustainability: By optimizing loading processes and reducing the number of trips required to transport goods, the system contributes to lower fuel consumption, emissions, and environmental impact.

Data-driven decision-making: The system generates valuable insights into loading patterns and trends, empowering operators to make informed decisions and optimize freight management strategies over time.

9. CONCLUSION

In conclusion, the transportation of coal by Eastern Coalfields Limited faces multifaceted challenges, resulting in avoidable expenses and financial losses. These issues encompass route selection, rehandling of coal, accurate weighing, demurrage charges, and underloading penalties. To address these challenges, a comprehensive IoT solution is proposed, aiming to minimize financial losses, optimize operational efficiency, enhance accountability, ensure compliance, and provide real-time monitoring. This transformative initiative, bolstered by blockchain security and AI-based chatbot support, seeks to not only reduce costs and improve transparency but also boost revenues and safety. However, it's essential to acknowledge the initial investment, complexity, and maintenance requirements associated with IoT implementation as potential challenges.

ACKNOWLEDGMENT

Our sincere appreciation goes out to everyone who helped us to successfully finish this project. First and foremost, we want to express our gratitude to **Prof. Anil Kumar Pathak** for his help and assistance, which has been invaluable to us in solving each issue that has arisen. Their feedback was crucial in helping to improve the system's accessibility and usability.

To conclude, we express our gratitude to our families, friends, and coworkers for their unwavering support and spiritual encouragement during the project. Without their help, we could not have finished this job. I appreciate your contributions, everyone.

REFERENCES

[1] Design on the Integrated Transportation Management System for Coal Company Wen-Feng Li; Yong-Ming Feng; Hai-Peng Lei 2016 International Symposium on Computer, Consumer and Control (IS3C) Year: 2016Conference Paper Publisher: IEEE

[2] Web-based Application Design for Coal-Transportation Networks of Thermal Power Plant Da-Ren Chen; Ye-Zheng Chen 2019 International Conference on Power Generation Systems and Renewable Energy Technologies (PGSRET)
Year: 2019 Conference Paper Publisher: IEEE

[3] Optimization of Coal Transportation Path Based on Dijkstra and Genetic-Simulated Annealing Algorithm Junqi Liang; Xinpeng He 2021 4th International Symposium on Traffic Transportation and Civil Architecture (ISTTCA)
Year: 2021 Conference Paper Publisher: IEEE

[4] Intelligent Control System of Coal Mine Main Transportation Based on Machine Vision Yongqing Lv; Ning Liu; Cungen Xi; Minghui Zhao 2021 4th International Conference on Artificial Intelligence and Big Data (ICAIBD) Year: 2021 Conference Paper Publisher: IEEE

[5] Regional coal transportation of closed-loop in China: Time series and spatial analysis Jinyan Yu; Weidong Liu; Liang Wang; Zhipeng Tang 2011 International Conference on Remote Sensing, Environment and Transportation Engineering Year: 2011 Conference Paper Publisher: IEEE

[6] Processes Optimization of Railway Coal Logistics Center of Eastward Coal Transportation from Xinjiang Yang Yu; Lin Wang 2012 Third International Conference on Digital Manufacturing & Automation Year: 2012 Conference Paper Publisher: IEEE

[7] Violation in coal transportation based on evolutionary game theory Zhang Chang-lu; Tan Zhang-lu 2014 11th International Conference on Service Systems and Service Management (CISM) Year: 2014 Conference Paper Publisher: IEEE

[8] Methods for safety mining of protective coal pillar under highway in China Weinan Deng; Huaxing Zhang 2011 International Conference on Remote Sensing, Environment and Transportation Engineering Year: 2011 Conference Paper Publisher: IEEE

[9] Health management of coal storage, transportation, and loading equipment based on predictive maintenance with vibration perception Yajing Xiao; Hui Wu; Yaodong Zhang; Shiji Yao 2022 2nd International Conference on Computer Science, Electronic Information Engineering and Intelligent Control Technology (CEI) Year: 2022 Conference Paper Publisher: IEEE

[10] Transportation and storage problems for regional power coal allocation planning of China Debin Fang; Ming Zhang; Chun Ye 2010 2nd International Conference on Advanced Computer Control Year: 2010 Conference Paper Publisher: IEEE Long-distance gas medium pipeline transportation—Coal as an example Yongsheng Qian; Xiaoting Yin; Peng Sun; Zhengzheng Ren; Zhidan Lv 5th Advanced Forum on Transportation of China (AFTC 2009) Year: 2009 Conference Paper Publisher: IET