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Informatics

Enhancing Service Quality through Railway Transportation Digitalization

Lily Petriashvili*, Tamar Lominadze*, Mzia Kiknadze*, Nona Otkhozoria*, Taliko Zhvania*

Georgian Technical University, Tbilisi, Georgia

(Presented by Academy Member Ramaz Khurodze)

Georgia's highways form a crucial segment of the Transcaucasian transportation network, serving as a central corridor connecting Europe and Asia. Positioned advantageously as a maritime gateway, Georgia emerges not only as a pivotal logistics hub but also as a vital transit route between continents, including the key linkage between Europe and China. Leveraging this strategic position, the Transcaucasian region stands to reap substantial economic gains through the enhancement of transit and logistics infrastructure and adoption of advanced technologies. To realize this potential, there is a pressing need to expand logistics infrastructure and embrace innovative technologies. A primary focus in this endeavor is the integration of digital technologies to streamline logistic processes. Additionally, the optimization of railway systems globally underscores the importance of effective management practices in Georgia. Essential to this effort is the efficient tracking and management of freight wagons, facilitated by unique identifying numbers that denote ownership and characteristics. Adherence to international agreements necessitates the prompt return of foreign wagons and those belonging to domestic railway companies, with penalties for delays. However, effective management of the extensive wagon fleet poses significant challenges. Currently, railway personnel are tasked with manually identifying and tracking wagons, a labor-intensive process prone to errors. Digital solutions offer promise in streamlining these operations, reducing time and costs associated with railway logistics, thereby enhancing efficiency and competitiveness in the transportation sector. This paper examines the implementation of an integrated system utilizing modern technologies, including optoelectronic video surveillance and radio frequency detection, to monitor moving wagons autonomously. The system aims to provide real-time information to relevant service teams, offering benefits such as enhanced railway network management, reduced freight transportation duration and operational expenses, and improved real-time wagon inventory management, ultimately boosting competitiveness in the railway cargo transportation sector. © *2025 Bull. Georg. Natl. Acad. Sci.*

digitalization, identification, optoelectronic, RFID

Georgia's railway infrastructure plays a crucial role in its economic development. Enhancing productivity in the railway freight transportation sector through advanced technology deployment, innovative methodologies, information and communication technologies in management are essential for maximi-

zing its positive impact. Currently, JSC Georgian Railways handles approximately 17 million tons of freight turnover annually, operating a fleet of around 1,500 wagons daily, comprising 800 loaded and 700 empty wagons. The manual recording and data entry process for each empty wagon, taking roughly 6 minutes per wagon, results in significant operational demands, requiring approximately 40 full-time staff members annually. This operational challenge is exacerbated by increasing cargo flow, contributing to a scarcity of qualified railway transportation personnel in Georgia.

JSC Georgian Railways incurs substantial expenses, approximately 360,000 GEL annually, solely on wages for wagon accounting. Automating this process would generate significant cost savings and mitigate financial losses associated with human-recorded transactions, including errors and discrepancies.

Digitizing wagon number readings presents an opportunity to automate digital data storage, reducing human errors and ensuring regulatory compliance within Georgian Railways. This digitized system would streamline return control processes and minimize fines for wagon owners.

If we compare the data published by the National Statistics Service of Georgia on the weight of cargo transported by railway from 2019 to 2023 by type of transportation (million tons), we can see the dynamics of data growth.

Methodology (Digitalization and Identification)

The global trend towards irreversible digitalization presents manifold opportunities across various sectors, with significant potential for augmenting the efficiency and efficacy of railway transportation systems. Embracing digitization is imperative for enhancing system functionality and user experience [1]. The development and implementation of an automated management framework for railway rolling stock and associated operations using digital technologies promise enhanced reliability, safety, and streamlined procedures with heightened transparency. Addressing concerns regarding data security is paramount to mitigate risks associated with unauthorized access and external interference in digital railway accounting processes.

Railway wagon identification numbers serve as indispensable data points facilitating collaborative planning and management of railway operations among railway operators, infrastructure entities, and governmental bodies. Timely and precise information regarding the whereabouts of rolling stock is essential for optimizing transportation management processes.

The prevailing manual input of initial operational data within the railway transportation workflow poses substantial challenges, including:

- ineffectiveness of control and management mechanisms;
- possible mistakes by operators;
- difficulty in ascertaining operational durations;
- partial completion of data input and delays in accessing/transmitting timely data.

To address these deficiencies and guarantee prompt and dependable data acquisition, it is imperative to devise a solution outlining the primary methodologies and strategies for the automated identification of rolling stock. The proposed remedy for the aforementioned issue is our real-time automatic identification system for railway rolling stock numbers. What distinguishes it from comparable systems is the innovative approach to number recognition, integrating optoelectronic and RFID technologies [2-4].

To evaluate the applicability and efficiency of RFID technology, a survey was administered targeting managers, regular employees, and IT personnel. A 5-point Likert scale was employed, offering the following choices:

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree.

The survey questions were formulated as follows: The use of RFID technology helps in reducing “waiting time.”

The use of RFID technology helps in reducing "improper handling."

The use of RFID technology helps to reduce "defects" in identification conditions.

The use of RFID technology contributes to the rapid handling of cargo.

A pivotal aspect of the concept involves the concurrent and autonomous functioning of both the optoelectronic and RFID components within the integrated system. This synchronization is facilitated through the utilization of artificial intelligence and machine learning algorithms. The outcomes from both components, namely the identified numbers, are autonomously transmitted to a computer program where sophisticated algorithms compare the received numbers and formulate conclusions regarding the identification of the rolling stock [5-7].

According to our framework, the optoelectronic system comprises video cameras positioned on both sides of the rolling stock, capturing its numbers. The system incorporates a corresponding computer software module that autonomously recognizes the number, both when the wagon is stationary and in motion. This recognition capability remains effective even if up to three out of the eight-digit numbers of the wagon are obscured by dirt or exhibit various forms of damage. This is achieved by capturing the numbers from both sides and conducting a comparative analysis, leveraging artificial intelligence techniques such as computer vision, artificial neural networks, and machine learning technologies. The software module evolves alongside the number recognition process, enhancing its speed and accuracy over time.

The integration of these technologies into the optoelectronic system sets it apart from similar systems. The implementation of this framework holds significant practical significance, optimizing time utilization, reducing operational expenses, and enhancing the efficient allocation of human resources. Moreover, it entails adjustments to the railway infrastructure, facilitating timely return control and mitigating fines for wagon owners. The digitization of wagon number readings automates digital data storage based on the layout (message codes) and stores it in a database. This approach minimizes human errors in the workflow, resulting in heightened efficiency in railway services, reduced operation times, and potentially lower service costs [8].

The implementation of the method and integrated system for identifying railway rolling stock numbers will substantially enhance automatic number recognition accuracy, reaching up to 95%. Furthermore, through the utilization of self-learning algorithms, this accuracy can potentially be further improved to reach up to 97%. Additionally, the time required for number identification will be reduced to a few seconds, with the possibility of further reduction to several tens of milliseconds. These attributes positively impact the service provided by Georgian Railways and the management of its rolling stock fleet.

To achieve these desired outcomes, methods and contemporary approaches will be employed to ascertain the principal characteristics and functional value of the system.

Conclusions

The implementation of an integrated system for identifying railway rolling stock numbers and the digitalization of wagon accounting processes present substantial opportunities for enhancing the efficiency and efficacy of operations within JSC Railways. The digitalization of wagon data enables automated storage and management of information, mitigating human errors and enabling timely return control, crucial for regulatory compliance. Embracing information and communication technologies in railway operations is essential for streamlining processes, enhancing service quality, and optimizing the utilization of personnel and resources.

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ინფორმატიკა

სარკინიგზო ტრანსპორტის მომსახურების ხარისხის გაუმჯობესება დიგიტალიზაციის გზით

ლ. პეტრიაშვილი*, თ. ლომინაძე*, მ. კიკნაძე*, ნ. ოთხოზორია*, თ. ჟვანია*

საქართველოს ტექნიკური უნივერსიტეტი, თბილისი, საქართველო

(წარმოდგენილია აკადემიის წევრის რ. ხუროძის მიერ)

საქართველოს სატრანსპორტო მაგისტრალები წარმოადგენს ამიერკავკასიის სატრანსპორტო ქსელის მნიშვნელოვან სეგმენტს, რომელიც ევროპასა და აზიას აკავშირებს ერთმანეთთან. საქართველო არის არამარტო მნიშვნელოვანი ლოგისტიკური ცენტრი, არამედ ის კონტინენტებს შორის სასიცოცხლო მნიშვნელობის სატრანზიტო მარშრუტს წარმოადგენს, მათ შორის, ის ევროპასა და ჩინეთს შორის ძირითადი დამაკავშირებელია. ამ სტრატეგიული მდებარეობის გამოყენებით ამიერკავკასიის რეგიონს შეუძლია მიიღოს მნიშვნელოვანი ეკონომიკური სარგებელი. არსებული პოტენციალის რეალიზაციისთვის აუცილებელი და მნიშვნელოვანია სატრანზიტო და ლოგისტიკური ინფრასტრუქტურის გაფართოება-გაუმჯობესება და ინოვაციური ტექნოლოგიების დანერგვა. ნაშრომში განხილულია ციფრული ტექნოლოგიების ინტეგრირების ლოგისტიკური პროცესების ოპტიმიზაციის საკითხი. ლოგისტიკური ინფრასტრუქტურის გაფართოება-გაუმჯობესების სფეროში განსაკუთრებული მნიშვნელობა ენიჭება ციფრული ტექნოლოგიების ინტეგრაციას ლოგისტიკურ პროცესებში. გადამწყვეტი მნიშვნელობა აქვს სატვირთო ვაგონების თვალყურის დევნებას და ეფექტურ მართვას, ამას ხელს უწყობს უნიკალური საიდენტიფიკაციო ნომრები, რომლებიც აღნიშნავს საკუთრებას და მახასიათებლებს. საერთაშორისო ხელშეკრულებები მოითხოვს უცხოური ვაგონებისა და შიდა სარკინიგზო კომპანიების საკუთრებაში არსებული ვაგონების სწრაფ დაბრუნებას, დაგვიანებისთვის ჯარიმებს. თუმცა, ვაგონების დიდი ნაკადის ეფექტურად მართვა მნიშვნელოვან გამოწვევებს ქმნის. ამჟამად, რკინიგზის მუშაკებს ევალებათ ვაგონების ხელით იდენტიფიცირება და თვალყურის დევნება, რაც შრომატევადი პროცესია და დიდია შეცდომის ალბათობა. ციფრული ტექნოლოგიების გამოყენებით შესაძლებელია ამ ოპერაციების გამარტივება, რაც შეამცირებს სარკინიგზო ლოგისტიკასთან დაკავშირებულ დროსა და ხარჯებს, რითაც გაზრდის ეფექტურობასა და კონკურენტუნარიანობას ტრანსპორტის სექტორში.

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