ENGINEER

international scientific journal

ISSUE 3, 2025 Vol. 3

E-ISSN 3030-3893

ISSN 3060-5172

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ENGINEER

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E-ISSN: 3030-3893

ISSN: 3060-5172

VOLUME 3, ISSUE 3

SEPTEMBER, 2025

engineer.tstu.uz

TASHKENT STATE TRANSPORT UNIVERSITY

ENGINEER

INTERNATIONAL SCIENTIFIC JOURNAL
VOLUME 3, ISSUE 3 SEPTEMBER, 2025

Founder of the international scientific journal “Engineer” – Tashkent State Transport University, 100167, Republic of Uzbekistan, Tashkent, Temiryo‘lchilar str., 1, office: 465, e-mail: publication@tstu.uz.

The “Engineer” publishes the most significant results of scientific and applied research carried out in universities of transport profile, as well as other higher educational institutions, research institutes, and centers of the Republic of Uzbekistan and foreign countries.

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Tashkent State Transport University had the opportunity to publish the international scientific journal “Engineer” based on the **Certificate No. 1183** of the Information and Mass Communications Agency under the Administration of the President of the Republic of Uzbekistan. **E-ISSN: 3030-3893, ISSN: 3060-5172.** Articles in the journal are published in English language.

Digitalization of maintenance record-keeping for automation and telemechanics devices at railway stations

N.V. Yaronova[1][a], **Sh.B. Otakulova** [1][b]
[1]Tashkent state transport university, Tashkent, Uzbekistan

Abstract: The article addresses the issues associated with the manual method of recording maintenance for automation, signaling, and telemechanics devices at railway stations in Uzbekistan. It analyzes the current practice of maintaining paper documentation and identifies major shortcomings, including high labor intensity, input errors, delays, and lack of transparency. A digital record-keeping model is proposed, which includes a workflow algorithm, registration and analytics modules, as well as integration with maintenance schedules. The practical importance of transitioning to an automated system is substantiated. The expected outcomes include increased reliability, cost reduction, and improved management of technical processes.
Keywords: automation, telemechanics, signaling and interlocking, digital model, maintenance, railway station, electronic logbook, digitalization.

1. Introduction

Modern conditions for the operation of railway transport demand high reliability and fault tolerance of technical systems, especially automation, telemechanics, signaling, and interlocking devices. Train traffic safety, operational efficiency, and adherence to transport schedules directly depend on the timely and high-quality maintenance of these systems. In this context, not only the technical service ability of the equipment becomes crucial, but also the organization of monitoring, recording, and analyzing maintenance activities.

At railway stations in Uzbekistan, the maintenance of signaling and interlocking devices is carried out in accordance with NSH-01 and NSH-03 instructions, which are approved as internal regulatory documents of JSC “Uzbekistan Railways” These documents define the frequency, methods, and formats for recording completed maintenance tasks. Currently, the primary method of documentation remains manual entry into paper logbooks (PU–67, DU–46, SHU–2, SHU–45, SHU–58, SHU–60, etc.). However, operational experience shows that this system no longer meets the demands of the digital era and gives rise to a number of issues: delays in data entry, a high risk of errors, lack of a unified database and transparent oversight, and the inability to quickly retrieve information.

An analysis of the literature confirms the relevance of this issue. In sources [1–3], the importance of a reliable maintenance record - keeping system is emphasized in the context of preventing railway incidents. Works [4–6] explore digital maintenance solutions based on integration with SCADA systems, digital twins, and artificial intelligence. Studies [7–9] highlight the significance of timely failure analysis and recurring fault detection as a foundation for predictive maintenance. International publications [10–13] showcase successful implementations of electronic maintenance and diagnostic systems by railway companies in Europe and Asia, which have led to significant cost reductions and improved operational control.

Moreover, reports from the UIC (International Union of Railways) indicate that in countries with advanced digital infrastructure, the average response time to S&I device failures is reduced by 30–50%, while compliance with technical regulations increases to 90–95% with the implementation of digital models. This makes digitalization not only an innovative step but also a necessity for ensuring the competitiveness of the national railway industry.

In the context of the active digital transformation of JSC “Uzbekistan Railways” and the modernization of its technological infrastructure, there is an urgent need to develop an automated system for recording and monitoring the maintenance of automation and telemechanics devices. This system should replace paper logbooks, ensure transparency of all operations, provide instant monitoring capabilities, access to historical records, and integration with preventive maintenance schedules.

The aim of the study is to develop and justify a methodology for the digitalization of processes related to the execution and recording of maintenance for automation and telemechanics devices, based on an operational-technological schedule. This methodology is intended to enhance the accuracy, transparency, and efficiency of maintenance control. To achieve this, the following research objectives have been set:

1. To analyze the existing documentation system and logbook practices related to the maintenance of signaling and interlocking devices.
2. To identify the main drawbacks of manual data entry and their impact on process reliability.
3. To develop an algorithm for creating an electronic database of completed maintenance tasks.
4. To evaluate the advantages of the digital model compared to the current system.
5. To propose practical recommendations for implementing an automated maintenance registration system at railway stations.

[a] https://orcid.org/0000-0003-1781-5597
[b] https://orcid.org/0009-0006-4415-963X

2. Research methodology

In the course of this study, a comprehensive approach was employed, combining both theoretical and practical methods of analysis aimed at identifying the shortcomings of the existing maintenance system for automation and telemechanics devices, as well as substantiating the need to transition to a digital model for planning and recording technical operations. To achieve the research objective, a combination of empirical and analytical - descriptive methods was applied.

Three major railway stations in Uzbekistan were conditionally selected as the objects of this study. These stations differ in traffic intensity, structural complexity, and the variety of automation devices in use: Tashkent-Severny Station – a junction station with high-density passenger and freight traffic, equipped with automatic switch machines, light signaling systems, SAUT devices, and centralized control systems; Samarkand Station – an intermediate transit station with a well-developed system of inter-station communication and remote monitoring; Karshi Station – a regional hub where telemechanics and locomotive signaling devices are actively used, and maintenance is performed on-site.

These stations were chosen due to their typical representativeness, which allows the results obtained from the study to be extrapolated to the entire railway transport system of Uzbekistan. Methods used to obtain reliable data:

Analysis of operational documentation. Maintenance registration logbooks used at the selected stations were examined in detail. The analysis covered the following forms: PU–67 (Shift Handover Log); DU–46 (Inspection Log for Switches, Tracks, and Overhead Contact Lines); SHU–2 (Log of Completed Work on Communication Facilities); SHU–45 (Electrical Measurements of Ground Resistance); SHU–58, SHU–60, and others. The evaluation focused on completeness of entries, presence of errors, duplicate records, and time gaps between events.

Time-and-motion observations. During the modeling process, the average time required by workers to perform manual journal entries was recorded. The observations included: Receiving a task; Executing the task; Locating the correct logbook; Filling in the required fields; Confirming instruction compliance; Performing control checks. Additionally, the time needed to retrieve archived records upon request was measured.

Expert survey. A survey was conducted with six specialists electromechanical engineers and heads of maintenance divisions with hands-on experience at maintenance sites. Participants were asked to assess the usability of the current system, identify major challenges, and predict the potential benefits of introducing an automated record-keeping system.

Algorithm modeling. Based on the analysis of current workflows, an algorithm was developed for the creation and operation of a digital database designed to replace manual logbooks. The model considers the location of maintenance (station, track segment, switch, signal), type of device, type of service, and maintenance frequency.

SWOT analysis. A comprehensive SWOT analysis was carried out to evaluate the strengths and weaknesses of the existing manual record-keeping system, along with identifying potential risks and opportunities associated with digitalization.

During the study, several key parameters were identified to construct a comparative analysis, as illustrated in fig. 1.

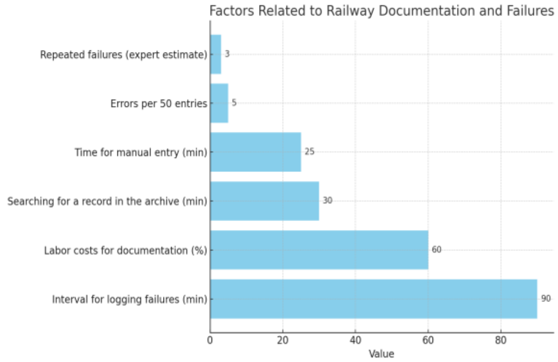

Fig. 1. Analysis of problem areas in manual record - keeping (Pareto Chart)

As shown in table 1, the key indicators of manual record-keeping reveal high labor intensity, frequent delays, and a significant risk of errors.

Table 1

Indicators for Evaluating Logbook-Based Maintenance Processes

№	Indicator	Description
1	Average time for manual record entry	Measured for each type of logbook (in minutes)
2	Time to retrieve information from logbook archives	From request submission to finding the required entry
3	Number of errors and omissions in the logbook	Includes untimely or incomplete entries
4	Number of device failures	Compared against logbooks and response times
5	Labor input for documentation	Calculated in person-hours per month
6	Interval between failure and its registration	Assessed in terms of its impact on downtime
7	Recurrence of failures	Analyzed causes related to unrecorded defects
8	Number of completed tasks not recorded in the logbooks	Based on local surveys and logbook reviews

Based on these indicators, conclusions were drawn about the inefficiency of the existing system and the necessity of transitioning to an electronic format. The collected data were subjected to a systematic analysis. Statistical calculations made it possible to determine the average and extreme values for each parameter.

Performance indicators and problem areas of manual maintenance record keeping for signaling and interlocking devices.

It should be noted that the study was conducted under preliminary modeling conditions, without deploying the system at actual sites. Therefore, some of the findings are of a predictive nature. Nonetheless, the results obtained can serve as a solid foundation for a pilot implementation of the digital system at selected stations, with subsequent scaling.

Developed method

At railway stations in Uzbekistan, maintenance of signaling, centralization, and interlocking devices, as well as telemechanics, is carried out in accordance with the regulations set out in instructions NSH-01 and NSH-03. Paper logbooks are used to record completed work, including:

PU–67 – Shift Handover Log, registering briefings and checking device status;

DU–46 – Inspection Log for outdoor cables, the overhead contact system, and switches;

SHU–2 – Log of completed work on communication facilities;

SHU–45 – Ground Resistance Measurement Log;

SHU–58, SHU–60, SHU–61, etc. – Specialized logs for diagnosing specific subsystems.

Each device type or maintenance activity has its own form of documentation, all of which must be filled out manually. Despite established practices, the paper based logbook system has a number of significant short comings that limit the effectiveness of maintenance management. Based on data analysis and expert interviews, the following problem areas were identified:

1. High labor intensity of data entry. Filling out each logbook entry takes on average 5–12 minutes. Given the volume of daily inspections, this task consumes up to 20 % of field personnel's working time, reducing their productive capacity.
2. Lack of transparency and real time oversight. Management cannot assess in real time whether work is being performed according to schedule, identify delays, or monitor fault repair progress. Oversight is only possible via on site audits or selective record checks.
3. Delays in information reporting. When faults or deviations occur, entries are not made immediately but only after the work is completed. The interval between an event and its registration can reach several hours- especially under high workload or staff shortages- making it difficult to detect critical recurring failures and risking fault accumulation.
4. Increased likelihood of errors. Manual entry leads to omissions (blank lines), spelling mistakes, incorrect time/date formats, duplicated information, and inconsistencies between different logs (for example, between PU–67 and SHU–2).
5. Difficulty in retrieving and analyzing information. Finding a specific record in the archives is time- consuming- particularly when searching for entries from previous months or for a particular device. This reduces the efficiency of repair planning, complicates compliance monitoring, and hinders report preparation.
6. Inability to perform automated analysis. The paper format precludes generating failure trend charts, ranking faults by criticality, or issuing automatic alerts for violations. Manual logs cannot integrate with planning or control systems (such as SCADA, ERP, or DCS).Rock S.M. [5] in his opinion, the configuration in a sitting position is characterized by balanced physiological curves of the column of the spine, the axis of the spine is decisive as the support of the human body.

As a result of analyzing 56 completed logbooks from three stations, the following typical issues were identified: in 18 % of cases the responsible person's signature was missing; in 22 % of cases the precise time of fault resolution was not recorded; in 31 % of cases discrepancies were found between the on-duty logs and the final record of completed work; 14 % of entries contained a mismatch between the type of work performed and the logbook form; and in 11 % of cases entries were duplicated or misdated. These violations indicate that the manual recording format does not ensure the accuracy or completeness of documentation, which, in turn, can compromise train traffic safety. Thus, the analysis of the current state shows that the existing paper-based system: Fails to meet the requirements of digital transformation in the railway sector; Creates safety risks; Hampers control and management processes; Requires significant time and labor resources.

Against this backdrop, it becomes clear that there is an urgent need to develop and implement an automated system for recording and monitoring maintenance activities, one that will ensure the timeliness, transparency, and reliability of all operational information. development of a digital record-keeping model and operating algorithm. The purpose of developing the digital model is to automate the processes of registering, storing, and analyzing data on the maintenance of automation and telemechanics devices at railway stations. The new system must replace paper logbooks, eliminate the shortcomings of manual data entry, and ensure the reliability, accuracy, and availability of information at all levels of operational management. The design of the digital model is based on the following principles:

-Centralized data – all information is stored in a single database;

-Transparency and accessibility – each user (dispatcher, electromechanic, engineer) has real-time access to the appropriate level of information;

-Integration with maintenance schedules – work data are synchronized with annual, monthly, and weekly plans;

-Data security – enforced via user authentication, backups, and digital signatures;

-Automated analytics – the system generates alerts for overdue tasks, repeat failures, and deviations from regulations.

The digital record-keeping model comprises the following key components:

1. Work registration module. The electromechanic or responsible staff member logs planned or unplanned maintenance via a digital form, specifying:

-Equipment name

- Start and end times of the task

-Type of intervention (inspection, replacement, measurement, etc.)

-Detected deviations and corrective actions

-Electronic signature

2. Maintenance-schedule monitoring module. The system automatically compares completed tasks against approved schedules (annual, monthly, weekly), instantly flagging any delays or omissions.

3. Emergency notification and diagnostics module. When a failure is recorded, an event card is created containing a timestamp, location, cause, and actions taken. On repeat failures, the system marks the segment as "problematic" and issues an alert for an unscheduled inspection.

4. Statistics and reporting module automatically generates:

- Logs in the formats of PU–67, DU–46, SHU–2, etc.
- Summaries of failures over a selected period;
- Deviation charts;
- Personnel performance tables;

- Plan vs. actual comparisons
5. User Interface
- Access via web interface or tablet;
- Mobile app for field work;
- Simple, intuitive interface with templates and prompts;

Operating algorithm of the digital maintenance system:

1.Create and upload the operational-technological schedule (by asset, deadline, responsible party);

2. Assign tasks to personnel (through the system or mobile interface);

3. Perform work and record results (enter parameters, capture photos, sign off);

4. Automatic compliance check against the schedule (plan vs. actual, detect deviations);

5. Generate reports and analytical charts;

6. Archive and centrally store data;

7. Issue alerts for deviations or critical events.

According to preliminary estimates, the implementation of the digital system can achieve the performance metrics presented in table 2.

Table 2

Advantages of implementing the digital model

№	Indicator	Before digitalization	After implementation
1	Average data entry time	8–12 min	1–2 min
2	Information retrieval time	up to 25 min	Instant
3	Error rate	10–15 % of entries	<1%
4	Analytics and reporting	Manual	Automatic
5	Management access to data	None	real-time
6	Feedback on failures	once per shift	Instant

This diagram (Fig. 2) presents the decision-making process for carrying out and recording maintenance work on equipment based on an operational technological schedule. The flowchart starts by determining whether the required maintenance tasks have been completed at the site. Depending on the outcome (yes or no), the process follows separate paths, evaluating the frequency and quality of technical maintenance checks and entries in the logbooks. The diagram also includes detailed references to specific logbooks and the nature of maintenance activities performed, highlighting points where technical staff should conduct additional reviews or record information as necessary. The process ends once all required actions have been assessed and properly documented.

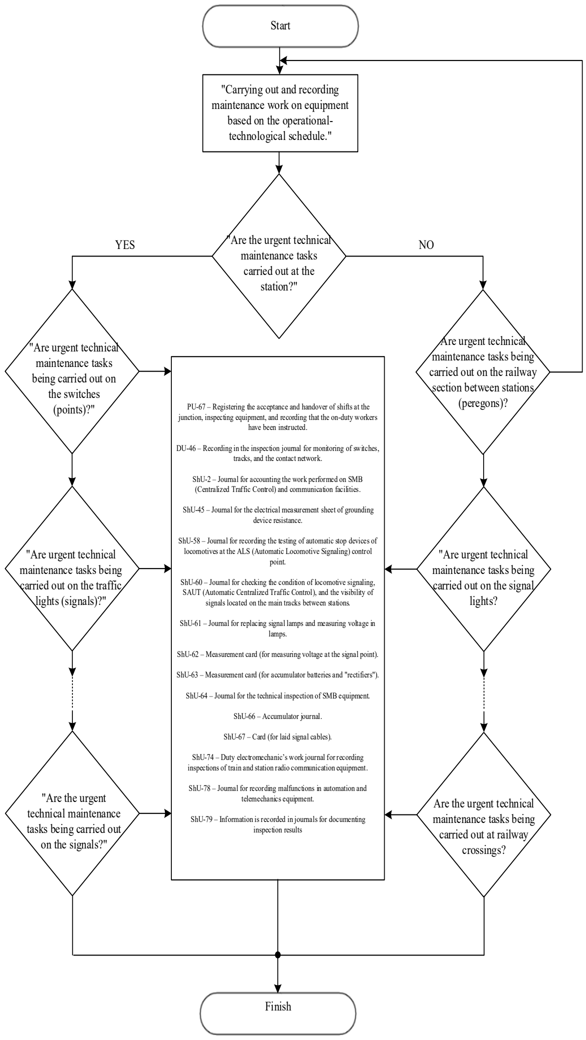

Fig. 2. The sequence of conducting and recording device service work based on the current operational-technological schedule. Impact of seat profile on posture

3. Results

Justification of the efficiency of digitalizing maintenance record-keeping for devices.

To provide an objective assessment of the need to switch from the manual to the digital method of recording maintenance for automation and telemechanics devices, let us examine the key parameters amenable to quantitative analysis. The manual logbook method is characterized by high labor intensity. Denote the average time to enter a single record as t_r, (in minutes) and the average number of entries per shift as n. Then the total time required for manual data entry is:

$$T_n = t_r \cdot n$$

This corresponds to approximately 40 % of working time-not directly related to maintenance-being spent on paperwork.

To assess the efficiency gain of the digital system, we introduce efficiency indicators E_r and E_d for the manual and digital systems, respectively. We define efficiency as a quantity inversely proportional to labor costs:

$$E = \frac{1}{T}$$

Then the relative increase in efficiency is defined as:

$$\Delta E = \frac{E_d - E_r}{E_r} 100\%.$$

If digitalization allows reducing the input time to $T_d = 50$ minut then:

$$E_r = 1/200, E_d = 1/50,$$
$$\Delta E = \frac{1/50 - 1/200}{1/200} 100\% = 300\%.$$

Thus, efficiency increases threefold. The next important factor is the probability of errors. Let the probability of an error when entering a single record manually be p; then the probability of a correct entry is q = 1 - p. The probability that all n entries will be correct is:

$$P = q^n$$

Failures of automation devices can be modeled as a poisson stream of events. Then the probability P(k) that k failures occur within time t, given an average failure rate λ, is determined by the formula:

$$P(k) = \frac{(\lambda k)^k}{k!} e^{-\lambda t}.$$

Digitalization helps reduce λ by enabling timely registration of failures and prompt responses to them.The formalization of the digital logging algorithm can be described using a logical structure. Let the fact of performing a task be denoted as W_i, and the fact of its registration in the system as R_i.Then the correct execution and logging of a task is expressed as:

$$D_i = W_i \wedge R_i.$$

If an array of such operations is formed:

$$\vec{D} = [D_1, D_2, \dots, D_n],$$

then the total number of correct entries:

$$\sum_{i=1}^{n} D_i = n,$$

will indicate 100% completeness and accuracy of the registration. The digital system enables monitoring and control of this condition automatically.

Thus, the presented quantitative assessments demonstrate that the digitalization of maintenance logging for signaling and interlocking (SIL) systems significantly reduces labor costs, improves the accuracy of records, and shortens response time to failures- ultimately enhancing the safety and efficiency of railway transport.

4. Conclusion

This study has examined the current issues associated with the manual method of recording and registering the maintenance of railway automation and telemechanics equipment at railway stations in Uzbekistan. The analysis showed that the existing system, based on paper logbooks, is characterized by high labor intensity, low efficiency, lack of transparency, and the inability to perform automated data analysis. These shortcomings create significant risks for both operational reliability and overall railway traffic safety.Based on the identified deficiencies, a conceptual digital model was developed to enable automated work registration, monitoring of maintenance schedules, and generation of statistical and diagnostic reports. The model includes a structured algorithm of actions, analytical modules, and tools for integration with existing railway infrastructure information systems.

The practical value of the proposed approach lies in its potential to: significantly reduce paperwork-related labor costs,improve the accuracy and completeness of records, accelerate response to technical deviations, enhance compliance with maintenance regulations, and ensure end-to-end digital traceability of all operations.

The planned phased implementation process (pilot project, scaling, and broader rollout) will help minimize transition risks and adapt the system to real-world operating conditions. The expected outcomes include both direct cost savings and increased infrastructure reliability - a critical factor under growing railway traffic demands.Thus, the proposed digital system can become an effective tool for modernizing the operational activities of automation and telemechanics services, contributing to the further development of Uzbekistan's intelligent transport infrastructure.

References

[1] Akhmedov S. "Methods of technical maintenance in railway automation and telemechanics systems". "Railway publishing house"-2020. pp. 156.

[2] Abdurakhmonov A., Yusupov, Sh. "Automation and telemechanics in railway transport" Tashkent: TATU-2019

[3] "Uzbekiston Railway". Instructions for the maintenance of automation and telemechanics devices (NSH-01 & NSH-03). Internal regulatory document.

[4] Savinkov. A. V., Lapshin. S. A. Digitalization of maintenance based on SCADA systems in railway infrastructure.-2022. "Automation, communication, informatics", vol.3, pp. 23–28.

[5] Kiselev. V.N., Matveev, S.D. Information-diagnostic systems for monitoring the technical condition of rail circuits. "Transport systems and technologies"-2020. vol. 4, pp. 40–46.

[6] Makhmudov. A.,and Kadyrov, Zh. Electronic journals in railway communication management: Experience and prospects.-2022. "Engineering Bulletin of Uzbekistan" vol. 1, pp. 15–22.

[7] Yunusov. B. Analysis of failures of signaling devices and methods to improve their reliability. ""Transport equipment and technologies"- 2021. vol. 2, pp. 33–37.

[8] Zhang. H., Liu. Y., and Chen. J. Predictive maintenance of railway signaling systems using AI algorithms. "IEEE Transactions on Intelligent Transportation Systems",- 2021. vol. 21, pp. 5202–5210.

[9] Kim. S., Choi, J. Development of a cloud-based maintenance platform for railway infrastructure. “Journal of Railway Engineering”.- 2021. vol.12(3), pp. 105–112. pp. 105–112.

[10] European Union Agency for Railways.Digital automatic train operation and maintenance standards. Brussels.-2021.

[11] International Union of Railways. Railway accident statistics report 2022. Paris: UIC Publications.

[12] Deutsche Bahn AG. Smart Maintenance: Zukunft der Instandhaltung bei DB Netz. Berlin.-2020.

[13] Japanese Railways Technical Research Institute (RTRI). Application of IoT and big data in train operation and maintenance. Tokyo.-2021.

Information about the author

Yaronova Natalya Valerevna	Tashkent state transport university, Department “Radio-electronic Devices and Systems” E-mail: tatochka83@list.ru Tel.: +998 90 966 91 89 https://orcid.org/0000-0003-1781-5597
Otakulova Shakhnoza	Tashkent State Transport University, Department “Radio-electronic Devices and Systems” E-mail: otaqulovashahnoza1998@gmail.com Tel.: +998 99 569 15 71 https://orcid.org/0009-0006-4415-963X

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