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The 8th International Conference on Technology, Education, and Social Science
“Navigating Global Transformation in an Uncertain World: Interdisciplinary
Perspective on Economics, Business, Education, Law, Agriculture, Food
Technology, Politics and Society” July 30th, 2026

PERFORMANCE EVALUATION OF AN RFID-BASED FIRE SAFETY EQUIPMENT IDENTIFICATION SYSTEM INTEGRATED WITH THE IZAT DIGITAL PLATFORM: A CASE STUDY AT A THERMAL POWER PLANT

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ABSTRACT

Routine inspection of fire safety equipment is a core element of occupational health and safety (OHS) management in power generation facilities, yet paper-based inspection is slow, prone to identification and recording errors, and difficult to trace. This case study evaluates an RFID-based equipment identification system, already in operation and integrated with the iZat (Zero Accident Assistant) digital inspection platform, at PT PLN Nusantara Power UP Tanjung Awar-Awar, Tuban, Indonesia. Between April and July 2025, data were collected on the inspection of 778 equipment units (440 portable fire extinguishers, 323 hydrant boxes with accessories, and 15 first-aid boxes) through direct observation, structured interviews with 25 respondents, and document review. Manual and RFID-iZat inspection were compared descriptively using a non-concurrent before–after design. Mean inspection time fell from 2.5 to 1.2 minutes per unit, a reduction of 52%. The recording error rate for equipment identity fell from approximately 7% to none in observed records, and the equipment data displayed after a tag scan matched the registered data in all observed scans. Because the comparison is uncontrolled and confined to one site, these figures are observational estimates, and they describe the integrated system rather than RFID alone. Reported constraints were tag loss and damage, areas with weak network coverage, the absence of supervisory validation of submitted reports, and the absence of the previous inspection result on the scan screen. The study contributes an empirical account of an operating RFID-integrated inspection platform in a thermal power plant, a mapping of system functions to the components that provide them, and a record of operational failure modes.

Keywords: RFID-based inspection; fire safety management; industrial inspection; performance evaluation; power generation; iZat

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INTRODUCTION

In Fire protection is among the most critical components of occupational health and safety (OHS) management in industrial facilities, and particularly in power generation plants, where continuity of operation and the safety of personnel depend on it. Portable fire extinguishers, hydrant systems, and related suppression equipment must remain operational to support an effective emergency response, and their periodic inspection and maintenance are expected under OHS management frameworks and extinguisher standards, including Indonesian Government Regulation No. 50/2012 (Government of the Republic of Indonesia, 2012), Ministerial Regulation No. 4/1980 on portable extinguishers, Ministry of Manpower of the Republic of Indonesia, (1980), ISO 45001, International Organization for Standardization, (1918), and NFPA 10, National Fire Protection Association, (1918).

Inspections have traditionally been recorded on paper forms or in standalone digital documents. Such practices are easy to introduce, but they are associated with identification and recording errors, lost reports, inspections that do not follow the schedule, and difficulty in retrieving past inspection records. These weaknesses reduce inspection efficiency and complicate maintenance decisions.

Digital technologies, including mobile and connected-worker solutions, are increasingly applied in OHS management (V. Patel, A. Chesmore, et. al, 2021). Radio frequency identification (RFID) identifies an object by reading the unique identifier of an attached tag without line of sight, and near-field communication (NFC), a short-range extension of contactless identification, allows an ordinary smartphone to read compatible tags, K. Finkenzeller, RFID, (2010), Ali, M., & Ajiatmo, D. (2020). Passive tags need no battery, which makes them attractive for equipment that is inspected at intervals.

Existing work on inspection of fire safety equipment, reviewed in Section 2, has examined barcode labelling, web-based inspection forms, QR-code and NFC applications, digital reporting tools, and passive RFID for inventory monitoring, Y. Gamaliel, et. al, (2020), D. Riwayanto & A. H. Z. Fasya, (2023), R. Sofian, et. al, (2023), E. H. Pratiwi, et. al, (2025), E. Y. Prastyanto, et. al, (2021), N. D. E. P. Suryani and F. Nurjati, (2025), N. Khan, et. al, (2020). To the authors' knowledge, empirical accounts of an operating RFID-integrated inspection platform in a thermal power plant, which also document where such a system fails, are scarce. The gap addressed here is therefore empirical: how large the change in inspection time and identification reliability is under real operating conditions, which functions of the integrated system plausibly account for it, and under what conditions the system breaks down.

The case is the iZat (Zero Accident Assistant) application used at PT PLN Nusantara Power UP Tanjung Awar-Awar Inspectors tap an RFID tag on the equipment with an NFC-enabled smartphone, complete a digital checklist, and upload the record to a central server, where planners and the OHS team can review it. The plant introduced

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the system to make inspections faster, more accurate, digitally documented, and visible to unit management and head office in real time.

This study addresses four research questions. RQ1: How does mean inspection time per equipment unit differ between manual and RFID–iZat inspection? RQ2: How do the incidence of equipment-identity recording errors and the conformity of displayed equipment data differ between the two procedures? RQ3: Which functions of the integrated system are provided by RFID and which by the iZat platform? RQ4: Which operational constraints affect reliability, and what mitigations follow from them?

The study makes three contributions. It provides an observational performance evaluation of an operating RFID–iZat system in a thermal power plant. It documents the operating mechanisms specific to iZat, namely weekly scheduling with carry-over, tag-to-schedule matching, offline mode, and dashboard monitoring, and maps each function to its providing component. It reports operational failure modes together with their risk implications. It does not claim a new technology, method, or theory, and it does not seek to generalise beyond the case studied. The remainder of the paper reviews related work (Section 2), describes the method and the system (Section 3), reports results (Section 4), discusses mechanisms, constraints, and limitations (Section 5), and concludes (Section 6).

1. Related Work

Table 1 compares the studies most closely related to the present one. Characterisations of studies, Y. Gamaliel, et al, (2020), D. Riwayanto and A. H. Z. Fasya, (2023), R. Sofian, et. al, (2023), E. H. Pratiwi, et. al, (2025), E. Y. Prastyanto, et. al, (2021), N. D. E. P. Suryani and F. Nurjati, (2025) and S4A Access Systems, (2023) are taken from the cited sources as summarised by the authors, and study, N. Khan, (2020) is characterised from its published abstract.

Three patterns emerge. First, several studies improve identification alone, through barcode, QR code, or OCR, with limited integration into reporting. Second, web-based forms digitise the checklist but leave identification and data entry to the inspector. Third, passive RFID has been examined mainly for inventory monitoring. Among the studies reviewed here, none reports the performance of tag-triggered identification combined with a schedule-aware digital inspection workflow in an operating thermal power plant, or describes the conditions under which such a system fails. The present study addresses that combination as a single-site case and does not claim superiority over the approaches in Table 1, which were developed for other settings and evaluated on other terms.

Vendor material on RFID extinguisher monitoring reports reduced manual recording time, but it is not peer reviewed and gives no basis for comparison with the present results.

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Table 1. Comparison with related studies

Study	Approach	Reported scope and limitation	Relation to this study
Gamaliel et al. (2020)	Passive RFID for inventory monitoring in an Industry 4.0 context	Inventory monitoring; read success above 70%; recommends writable tags	Inspection workflow rather than inventory
Riwayanto & Fasya (2023)	Barcode labelling of extinguisher units	Reduces input errors and speeds recognition; no automated reporting or management dashboard	RFID identification with automated records and dashboard
Sofian et al. (2023)	Web-based inspection software	Online forms; static; no data visualisation or process automation	Tag-triggered, mobile, scheduled workflow
Pratiwi et al. (2025)	Web-based extinguisher inspection at a logistics company	Semi-manual data entry; no visual dashboard or automation	Identification by tag; dashboard monitoring
Prastyanto et al. (2021)	Android application using QR code and NFC for inspection and information of PLC equipment at a cement plant	Equipment other than fire safety equipment	Fire safety equipment in a power plant
Suryani & Nurjati (2025)	Digital extinguisher checking with the I-Reporter application	Reported benefits: data integration, easier audit, real-time access through a dashboard	Setting and identification method differ [12]]
Khan et al. (2020)	BIM-based planning of portable firefighting equipment and an OCR- and blockchain-based Android application for inspection information	Construction-site setting; concept validated with developed applications	RFID/NFC identification; an operating system evaluated in a power plant
S4A Access Systems (2023)	Vendor case study of RFID extinguisher monitoring	Not peer reviewed; reports reduced manual recording time and automatic alerts	Reports an operating plant with the method disclosed

METHODS

3.1 Research Design and setting

This is a no-experimental, single-site case study. It evaluates an existing system and does not design or develop one. The study was conducted at PT PLN Nusantara Power UP Tanjung Awar-Awar, a thermal power plant in Tuban Regency, East Java, Indonesia

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from April to July 2025. Performance was compared between the manual procedure and the RFID-iZat procedure using a non-concurrent before-after design without a control group. Analysis is descriptive. Figure 1 summarises the research workflow.

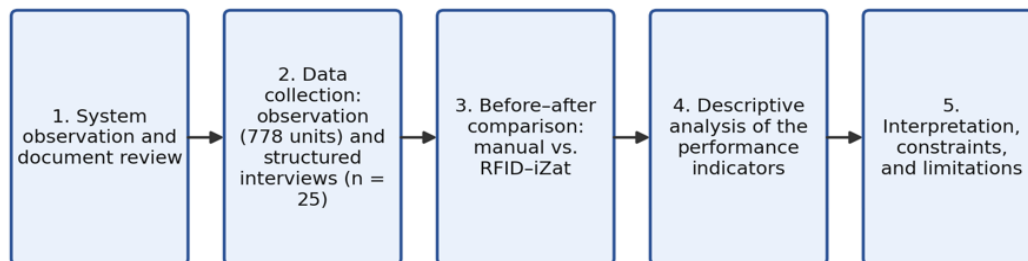


Fig. 1. Research workflow.

3.2 The iZat inspection system

iZat (Zero Accident Assistant) is the application used at the plant; version 2.1.5 was shown in the demonstration recording. Its users are organic employees of PT PLN Nusantara Power and personnel of related organisations with a work or project relationship to the company. The unit planner administrator registers the equipment type, the inspection checklist for each type, and a device master that sets the schedule frequency, the duration, and the number of inspectors; the procedure requires at least two inspectors. Equipment and tags are registered by the planner. Planners and the OHS team access the records for audit, evaluation, and reporting.

In the field, the inspector logs in with an employee ID and password. The Equipment Inspection module offers an Offline tab, from which the schedule is downloaded for use without a connection, and a separate History tab. The schedule shows the current week and, for equipment not yet inspected, the previous week. An item still uninspected after that disappears from the schedule and the equipment status becomes ‘not ready’. The inspection team goes to the equipment and taps the RFID tag with an NFC-enabled smartphone. If the tag is not in the schedule, the application shows a notification and the inspection cannot proceed. If it matches, the inspector completes the checklist created by the central planner, attaches photographs when needed, saves the record, and presses the Upload button, which works only when a connection is available. The record is then stored on the iZat server in the equipment’s history log. The inspection menu offers a dashboard with two tabs, infrastructure readiness and crew performance, and head office reviews both for each unit every week. Figure 2 shows the workflow.

3.3 Equipment and checklists

The study covered 778 equipment units: 440 portable fire extinguishers (APAR), 323 hydrant boxes with accessories, and 15 first-aid (P3K) boxes. Extinguishers are inspected with an eight-item checklist and hydrant boxes with a nine-item checklist; the first-aid box checklist. Every item is answered by the inspector’s own judgement, so the

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system fixes which unit was inspected and when, but not whether the physical condition was judged correctly. The hydrant checklist includes two periodic tests, a hydrostatic test every five years and a Pitot-tube flow test; these are not part of a routine inspection.

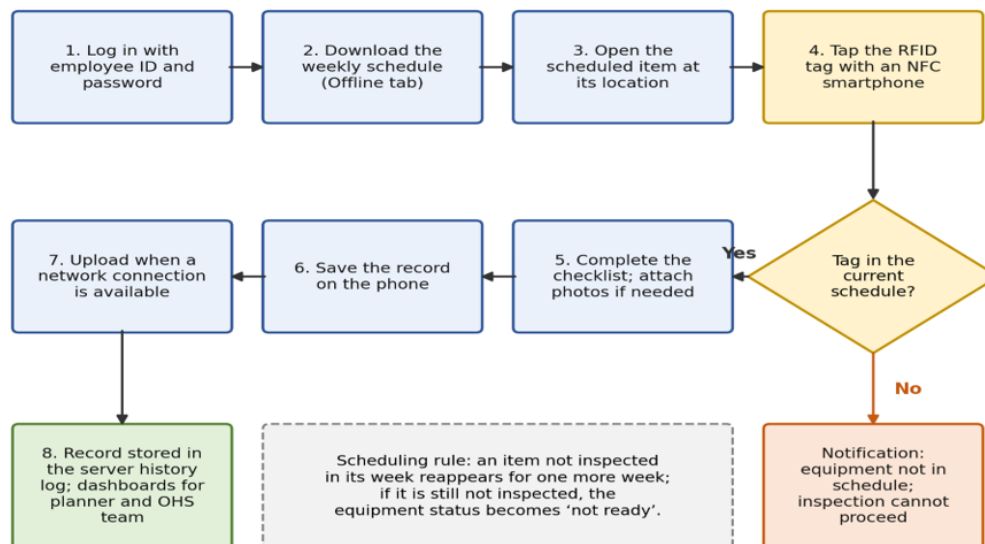


Fig. 2. The iZat inspection workflow with RFID tag identification

3.4 Data collection

Three data sources were used. First, direct observation of the inspection of the units listed above, covering the procedure, the use of RFID tags, and the use of the iZat application by OHS personnel, inspections timed. Second, structured interviews with 25 respondents, namely the unit planner administrator, inspection personnel, and other personnel involved in inspection and in recording data through iZat; respondents were selected on the basis of the equipment data. Third, document review of the inspection SOP, the iZat user guide, and the technical specification of the RFID devices.

Inspection time covers routine checklist items only, and the periodic tests described above are excluded. It was measured with intrumen from start to finish and refers to an inspection team. The manual baseline was obtained from observation of the earlier procedure and from historical records.

3.5 Performance indicators, analysis, and validity

Seven indicators were defined (Table 2), and each is reported in Section 4. Inspection time reduction is $(IT \text{ manual} - IT \text{ RFID-iZat}) / IT \text{ manual} \times 100\%$. Identity recording error rate is the number of inspection records in which the recorded equipment identity differed from the physical equipment, divided by the number of records observed. Data conformity is the share of observed tag scans in which the displayed data matched

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the registered data. Operational constraints, ease of use, and user acceptance come from the interviews and are reported as numbers of respondents per answer category.

The design has clear limits. The comparison is non-concurrent and uncontrolled, so learning effects, changes in staffing, and the presence of observers may influence the results. The error rate refers to equipment identity only, because checklist entries remain manual. The results come from one organisation over four months. Inferential statistics are not reported because; where per-inspection times exist, the mean, standard deviation, and range are given.

Table 2. Performance indicators and operational definitions

Indicator	Operational definition	Data source
Inspection time (IT)	Mean time per equipment unit, in minutes	Observation, inspections
Inspection time reduction (IE)	$(IT \text{ manual} - IT \text{ RFID-iZat}) / IT \text{ manual} \times 100\%$	Derived from IT
Identity recording error rate	Records with wrong equipment identity / records observed	Observation and record check, records
Data conformity	Tag scans with displayed data matching registered data / scans observed	Observation, scans
Operational constraints	Number of respondents per constraint category	Structured interviews, n = 25
Ease of use	Number of respondents per answer category	Structured interviews, n = 25
User acceptance	Number of respondents per answer category	Structured interviews, n = 25

Whether they are research articles or reviews, they should follow a specific methodology. The methodology used should also draw on previous research considered valid within the relevant field.

RESULTS AND DISCUSSION

4.1 Situation before implementation

Before the system was introduced, inspection results were recorded on paper or in standalone digital forms that were not connected to the central information system. Three

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problems were reported: lost inspection reports, errors in recording equipment identity, and inspections that did not follow the schedule.

4.2 Performance comparison

Mean inspection time fell from 2.5 to 1.2 minutes per unit (Table 3), a reduction of 52%. This agrees with the interview finding that an inspection takes less than 2 minutes. The error rate for equipment identity was approximately 7% under the manual procedure, and no error was observed in the records observed under the RFID–iZat procedure; the change is 7 percentage points. In all observed scans, the displayed data matched the registered data.

Table 3. Performance comparison before and after RFID–iZat implementation (observational, non-concurrent)

Parameter	Manual inspection	RFID–iZat inspection	Change	Basis
Mean inspection time per unit	2.5 min	1.2 min	–1.3 min (52%)	inspections;
Identity recording error rate	≈7%	0% in observed records	–7 percentage points	records
Displayed data conformity	Not applicable	100% of observed scans	—	scans
Equipment location identification	Depends on manual notes	Retrieved from registered data	Qualitative	Observation
Database integration	Not available	Records uploaded by the inspector when a connection is available	Qualitative	Observation, demonstration recording
Monitoring	No consolidated report	Dashboard of infrastructure readiness and crew performance, reviewed weekly by head office	Qualitative	Document review, interviews

4.3 Interview findings

Of the 25 respondents, found the application easy to use and the overall response to the RFID–iZat system was positive. The constraints respondents reported were damaged tags and weak signal. The documented constraints are analysed in Section 5.

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DISCUSSION

5.1 Mechanisms behind the observed differences

Four mechanisms in the workflow plausibly explain the observed differences. First, a tag scan replaces searching for and typing the equipment identity, which removes the step in which identity errors arose and shortens each inspection. Second, the application accepts only tags that are in the current schedule, so a record cannot be created against the wrong unit. Third, the digital form removes transcription from paper. Fourth, the scheduling rules push compliance: an unfinished inspection reappears in the following week, and equipment still uninspected afterwards carries a ‘not ready’ status. The design does not allow the contribution of each mechanism to be quantified.

5.2 Attribution to RFID and to the iZat platform

Table 4 shows that only identification is a property of RFID. Display of equipment data, schedule matching, digital forms, offline operation, history, and dashboards are provided by the iZat platform. The before–after comparison therefore measures the integrated system, and the results should not be read as the effect of RFID alone. A concurrent comparison of RFID with another identifier, such as QR codes, on the same platform would be needed to isolate it.

Table 4. Attribution of functions to system components

Function	Provided by	Basis
Unique identification of the RFID tag physical asset		Tag ID registered by the planner
Display of registered equipment data after a scan	iZat platform, triggered by the tag ID	Data entered by the planner
Rejection of a tag that is not in the current schedule	iZat platform, using the tag ID	Notification; inspection cannot proceed
Digital checklist, photo attachment, upload	iZat mobile application	Entries remain manual
Offline schedule download and deferred upload	iZat mobile application	Upload triggered by the inspector, not automatic
Weekly schedule with one-week carry-over; status ‘not ready’	iZat platform	Scheduling rules
History log and dashboards	iZat server	Access restricted to planner and OHS team

5.3 Operational constraints

Table 5 links each constraint to its mechanism and risk. Tag loss and damage affect reliability directly, because an unreadable tag prevents inspection and changes the schedule status. Metal surfaces attenuate the magnetic field used to read passive tags, so

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tag type and mounting position matter. Missing network coverage delays uploads and therefore supervisory visibility, which offline mode only partly offsets. The absence of supervisory validation means that entry errors and incomplete checklists are not caught, which matters because the checklist remains manual. Although a separate History tab exists in the inspection module, the scan screen does not show the previous inspection, so inspectors cannot compare with it on site. The quality of the checklist judgement itself, which remains manual, is not evaluated in this study.

Table 5. Operational constraints, mechanisms, risks, and mitigations

Constraint	Mechanism	Operational risk	Mitigation
Tags lost or damaged (scratches, excessive heat)	Tags are attached externally; metal surfaces attenuate the magnetic field	Equipment cannot be identified or inspected; status becomes ‘not ready’	Protective housing; tag type and mounting suited to metal
No network coverage in some areas	Upload requires a connection	Delayed records; delayed supervisory visibility	Offline schedule download; network reinforcement
No supervisory validation	Reports are final after upload	Erroneous or incomplete entries are not caught	Add an approval step for OHS supervisors
No previous-inspection view at the point of scanning	The scan screen shows registered data only; history is in a separate tab	Inspectors cannot compare with the previous inspection on site	Show the last inspection result on the scan screen
Training need for new staff	Procedure and application are new to them	Inconsistent inspection quality	Routine training and simulation

5.4 Comparison with related work and implications

The direction of the findings agrees with earlier reports that digitising identification and recording reduces manual entry and speeds inspection [8]–[12], but the present design does not support numerical comparison with them, because those studies differ in setting, technology, and measurement. The point of difference is the operating-plant evidence on a combined RFID and schedule-aware workflow, and the documented failure modes.

For practice, the findings point to four actions: protect tags against scratching and heat and mount them in positions suited to metal; keep the offline schedule and plan network reinforcement in weak-signal areas; add supervisory validation of submitted reports; and show the previous inspection result on the scan screen. The checklist includes

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items on expiry, damage, pressure, and seal condition, so the records can support preventive maintenance decisions, but the study did not measure any effect on equipment readiness or accident outcomes.

5.5 Limitations and future work

The results should be interpreted within the stated limits: a single site, a four-month period, a non-concurrent and uncontrolled comparison, interview data that reflect user perception, and an error definition limited to equipment identity. Future work should compare identifiers on the same platform, record per-inspection data to allow statistical analysis, evaluate the quality of checklist judgements, and test the proposed mitigations. Integration with IoT sensors and enterprise systems is a possible later development, not something this study evaluated.

CONCLUSION

This case study evaluated an RFID-based equipment identification system integrated with the iZat platform at a thermal power plant. Mean inspection time per unit fell from 2.5 to 1.2 minutes, and no equipment-identity recording error was observed under the integrated procedure, against approximately 7% under the manual one. These figures are observational and describe the integrated system, not RFID alone. Tag durability, network coverage, supervisory validation, and the absence of the previous inspection on the scan screen are the main constraints on reliability. The findings come from one organisation and do not establish effectiveness in other settings.

ACKNOWLEDGMENT

The authors thank PT PLN Nusantara Power UP Tanjung Awar-Awar for access to operational data and for supporting this research, and the Department of Electrical Engineering, Universitas Darul ‘Ulum Jombang, for academic support throughout the study.

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