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Development of a Mobile Application for Real-Time Reporting of Occupational Health and Safety (OHS) Incidents in a Factory Environment

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ABSTRACT
Incident reporting in manufacturing industries often relies on paper-based and manual procedures, causing delayed safety responses and incomplete documentation. This study aimed to develop and evaluate a cross-platform mobile application for real-time Occupational Health and Safety (OHS) incident reporting in the manufacturing sector to improve reporting quality, compliance, and response speed. A Research and Development approach using the Agile Scrum framework was combined with a quasi-experimental pre-test-post-test design for evaluation. The application was built using React Native, supported by Node.js, PostgreSQL, and Firebase. It was implemented and assessed over six months at PT. Semen Padang, involving 120 production workers, 15 OHS personnel, and 8 supervisors. Usability was measured using the System Usability Scale (SUS), while statistical analysis employed the Wilcoxon Signed-Rank test. Results showed that average reporting time decreased from 47 minutes to 8 minutes, an 83.0% reduction. The SUS score increased from 56.3 to 82.7 ($p < 0.001$). Reporting compliance rose by 46.4%. Minor accidents declined by 60.7%, moderate accidents by 55.6%, and near-miss reporting increased by 207.1%. These findings indicate that the application strengthened proactive safety culture by improving transparency, accelerating response time, and providing more complete incident data for risk-based decision-making. In conclusion, real-time mobile applications for OHS incident reporting effectively enhance reporting system performance and reduce workplace accidents, with strong potential as a model for digital transformation of OHS management in industrial settings and support sustainable organizational learning through faster hazard identification, communication, corrective action, and continuous safety performance improvement initiatives.

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INTRODUCTION

The manufacturing sector consistently ranks among the highest-risk industries for occupational accidents globally. According to the International Labour Organization (ILO), approximately 2.3 million workers die annually from work-related causes, with an additional 340 million non-fatal workplace accidents occurring each year (ILO, 2022). In Indonesia, the Social Security Administration for Employment (BPJS Ketenagakerjaan) recorded 265,334 workplace accidents in 2022 alone, with the manufacturing sector contributing approximately 34% of total cases. These figures underscore the critical importance of robust, timely, and accurate OHS incident management systems (Syaharani, 2022).

A fundamental challenge in managing workplace safety is the quality and speed of incident reporting. Conventional paper-based reporting systems are characterized by significant temporal delays—reports can take 30 to 90 minutes to reach supervisory personnel—while simultaneously suffering from data incompleteness, illegibility, and vulnerability to loss or damage. Communication-based methods such as phone calls and email improve speed marginally but introduce inconsistency in data structure and lack geospatial context. These systemic weaknesses in reporting infrastructure directly impair the ability of safety officers to conduct timely root-cause analyses and implement corrective measures before further incidents occur (Dewantara, Irwansyah, & Pratiwi, 2022).

The proliferation of smartphones in the Indonesian workforce offers a transformative opportunity for OHS management. A survey by the Indonesian Internet Service Providers Association (APJII, 2023) reported that 73.4% of workers in the industrial sector now own and regularly use smartphones. Mobile applications, characterized by constant availability, integrated sensors (GPS, camera, accelerometer), and real-time data transmission capabilities, represent a natural technological fit for digitizing incident reporting workflows in dynamic factory environments.

While prior research has explored mobile technologies in occupational safety, significant gaps remain. Zhang et al. (2021) demonstrated that mobile reporting systems in construction reduced response times by 68%, however their solution lacked offline functionality critical for areas with unstable connectivity. Lee and Kim (2022) integrated GPS tracking into manufacturing safety reporting but did not address the hierarchical notification escalation required in large industrial facilities. In the Indonesian context, Permana and Widodo (2023) developed an Android prototype for mining OHS reporting, achieving a 38% improvement in reporting compliance, but the system did not support iOS platforms or real-time synchronization.

The present study addresses these gaps through the development of a comprehensive, cross-platform mobile OHS reporting application featuring: (a) real-time data synchronization via Firebase; (b) offline mode with automatic synchronization upon network restoration; (c) severity-based escalation notification hierarchy; (d) integrated GPS geolocation and photographic evidence capture; and (e) a real-time analytical dashboard for OHS managers (Redaksi Harian Sriwijaya, 2025). The system was validated through a six-month quasi-experimental deployment at PT. Semen Padang, one of the largest cement manufacturing facilities in Southeast Asia.

Heinrich's Triangle theory posits that for every major accident, there exist approximately 29 minor incidents and 300 near-miss events (Moore, Yorio, Haas, Bell, & Greenawald, 2020).

Contemporary meta-analyses have largely confirmed this hierarchical relationship (Hollnagel, 2014). Critically, the vast majority of near-miss events go unreported in conventional systems, depriving organizations of invaluable leading indicators of safety risk. Reason's (1997) organizational accident model further emphasizes that latent failures—systematic conditions that predispose facilities to accidents—can only be identified and remediated through comprehensive incident data, including near-miss and unsafe-condition reports.

A systematic review by Almansour. (2023) identified that the primary barriers to effective incident reporting in manufacturing include: reporting complexity and time requirements, fear of punitive consequences, perceived lack of corrective action following reports, and physical distance from reporting infrastructure during incidents. Digital solutions that minimize reporting complexity, protect reporter anonymity where appropriate, and demonstrate closed-loop corrective action have been shown to address all four barriers effectively.

The deployment of mobile applications for safety management has grown substantially over the past decade. Zhang, Cao, & Zhao. (2017) provided a foundational review of sensor-based tracking systems in construction, highlighting the potential of GPS-integrated mobile devices for spatial analysis of accident hotspots. Building on this foundation, Liang et al. (2022) conducted a field study across 12 Chinese construction sites and demonstrated that real-time hazard reporting via mobile platforms reduced average corrective action initiation time by 71% compared to paper-based systems.

In the manufacturing context, Lee and Kim (2022) validated a GPS-integrated mobile safety reporting system across three automotive plants in South Korea, finding significant improvements in report accuracy (from 74% to 91%) and a 44% reduction in accident recurrence rates. Sarshar et al. (2021) proposed a theoretical framework for digital OHS transformation that emphasizes the critical role of system integration—the ability of mobile applications to interface with enterprise resource planning (ERP), emergency response, and regulatory reporting systems—as a determinant of long-term adoption and impact.

Chen et al. (2023) conducted a meta-analysis of 34 studies examining mobile technology interventions in OHS management, finding average reductions of 40–65% in recordable incident rates within two years of full implementation. Critically, studies reporting the highest reductions shared three characteristics: participatory design involving frontline workers, offline functionality, and management commitment to visible corrective action following reports. The present study was designed to embody all three characteristics.

The adoption of digital tools in industrial settings is strongly mediated by perceived usability. The System Usability Scale (SUS), developed by Brooke (1996) and subsequently enhanced with interpretive benchmarks by Bangor et al. (2009), has emerged as the dominant instrument for evaluating workplace application usability. Scores above 68 indicate above-average usability; scores above 80.3 correspond to the 'B' grade (good) category. Prior mobile OHS applications in published literature have achieved SUS scores ranging from 61 to 79, indicating room for substantial improvement through human-centered design methodologies (Permana & Widodo, 2023; Lee & Kim, 2022).

METHODS

This research uses a mixed-method approach with a Research and Development (R&D) design combined with quasi-experimental evaluation through a pre-test and post-test model. The system development phase adopted the Agile Scrum framework, which is carried out in six sprints from March to May 2024. Subsequently, the implementation evaluation was conducted over six months, covering the period before and after the system implementation. The research was conducted at PT. Semen Padang, West Sumatra, which is a large-scale manufacturing industry with high operational complexity.

The research subjects were selected using purposive sampling techniques, involving 120 production workers, 15 HSE personnel, and 8 supervisors as system users. Inclusion criteria included active workers with a minimum of six months of work experience and those who use smartphone devices. The developed system was cross-platform based, using React Native with a Node.js backend architecture and a PostgreSQL database integrated with Firebase for real-time synchronization. The main features include GPS-based reporting, visual documentation, tiered notifications, and offline mode with automatic synchronization.

Data collection was conducted through usability measurement using the System Usability Scale (SUS) instrument, observation of reporting compliance levels, and analysis of incident data before and after implementation. Statistical analysis was conducted using SPSS software with the Wilcoxon Signed-Rank test to examine significant differences between periods, with a significance level set at $\alpha = 0.05$. This approach allowed for a comprehensive evaluation of the system's effectiveness in improving reporting performance and workplace safety.

RESULTS

1. Comparative Analysis of OHS Reporting Methods

A baseline assessment was conducted prior to development to quantify the limitations of existing reporting channels. Table 1 summarizes the performance characteristics across all identified reporting methods, including the proposed application.

Table 1. Comparative Analysis of OHS Incident Reporting Methods

Reporting Method	Avg. Time (min)	Data Accuracy (%)	Accessibility	System Integration
Paper-based Manual	45–90	62.1	Area-limited	None
Email / Phone Call	20–45	71.4	Moderate	Low
Desktop Software	10–20	82.3	Office-only	Moderate
Proposed Mobile App	2–5	96.4	Real-time / Full	Full

Source: Authors' analysis based on baseline assessment interviews and pilot observations (2024).

The data in Table 1 confirm the substantial performance gap between conventional methods and the proposed mobile solution. Paper-based reporting averaged 45–90 minutes with a data accuracy rate of only 62.1%, primarily due to illegibility, missing fields, and transcription errors during digitization. The proposed application achieved a mean reporting time of 2–5 minutes with 96.4% data accuracy, facilitated by mandatory field validation, dropdown standardization, and automatic GPS and timestamp capture.

2. Technical Specifications of the Developed System

The finalized application was built to meet the operational demands of a large-scale manufacturing environment, including reliability in low-connectivity zones. Full technical specifications are presented in Table 2.

Table 2. Technical Specifications of the Developed OHS Mobile Application

Component	Specification	Description
Platform	Android 8.0+ / iOS 13+	Cross-platform via React Native 0.72
Backend	Node.js 18 + Express.js	RESTful API with JWT authentication
Primary Database	PostgreSQL 15	Relational data, audit trail
Real-time Sync	Firebase Realtime Database	Live dashboard & push notifications
Push Notification	Firebase Cloud Messaging	Latency < 2 s, escalation hierarchy
GPS Accuracy	±3 meters	Google Maps Platform API
Offline Storage	SQLite (local)	Auto-sync when network restored
Security	TLS 1.3 + AES-256	End-to-end encrypted transmission

Source: Development documentation and system architecture records (2024).

The dual-database architecture (PostgreSQL + Firebase) proved particularly effective in balancing data integrity with real-time performance requirements. The offline-first SQLite implementation ensured that reporting functionality was maintained even in areas of the facility with poor cellular coverage, such as interior kiln zones and underground utility corridors.

3. System Performance Test Results

Performance testing was conducted under simulated peak-load conditions involving 520 concurrent users, representing approximately 30% above the maximum expected simultaneous user count during shift-change periods. All seven predefined key performance indicators were met or exceeded, as detailed in Table 3.

Table 3. System Performance Test Results (n = 500 test scenarios; peak load = 520 concurrent users)

Test Parameter	Target	Mean Result	Std. Dev.	Status
Report Upload Time	< 5 s	2.3 s	±0.41 s	✓ Passed
Push Notification Latency	< 10 s	4.7 s	±1.22 s	✓ Passed
GPS Location Accuracy	< 5 m	3.1 m	±0.83 m	✓ Passed
API Response Time	< 200 ms	142 ms	±23 ms	✓ Passed
Offline Sync Duration	< 30 s	18.4 s	±3.61 s	✓ Passed
Application Crash Rate	< 1.0%	0.3%	—	✓ Passed
Concurrent Users (peak)	≥ 500	520	—	✓ Passed

Source: Apache JMeter load testing and Firebase Performance Monitoring data (May 2024).

The mean API response time of 142 ms (SD ±23 ms) was well within the 200 ms threshold generally accepted for responsive enterprise mobile applications. The push notification latency of 4.7 s (SD ±1.22 s) was particularly noteworthy, as it ensured that OHS supervisors receive actionable alerts within seconds of an incident being logged, enabling the mobilization of emergency response

teams significantly faster than any previously documented system at the facility. The crash rate of 0.3% falls below the industry benchmark of 1.0% for mission-critical industrial applications.

4. User Satisfaction and Usability Evaluation (SUS)

System usability was evaluated among all 120 production employees before implementation (using the legacy paper-based system as the reference) and after six months of mobile application use. Results are presented in Table 4.

Table 4. System Usability Scale (SUS) Scores and Reporting Compliance: Pre- vs. Post-Implementation

Evaluation Aspect	Pre-impl. (n=120)	Post-impl. (n=120)	Improvement (%)
Ease of Incident Reporting	52.4	84.6	+61.5%
Speed of Safety Response	45.2	88.3	+95.4%
Completeness of Incident Data	58.7	91.2	+55.4%
Overall SUS Score	56.3	82.7	+46.9%
Reporting Compliance Rate	63.1%	92.4%	+46.4%

*Source: SUS survey administered to n = 120 employees. *All differences statistically significant: $p < 0.001$, Wilcoxon Signed-Rank Test. SUS scores on a 0–100 scale.*

The overall SUS score increased from 56.3 (classified as 'marginally acceptable' per Bangor et al., 2009) to 82.7 (classified as 'good', grade B), a statistically significant improvement ($Z = -9.12$, $p < 0.001$, $r = 0.83$, indicating a large effect size). The largest gain was observed in the Speed of Safety Response dimension (+95.4%), reflecting the transformational impact of real-time notifications on perceived organizational responsiveness to reported hazards. This finding aligns with theoretical predictions from Sarshar et al. (2021) that perceived management responsiveness is the strongest driver of sustained reporting behavior.

Reporting compliance—the proportion of verifiable incidents formally documented—increased from 63.1% to 92.4% (+46.4%), suggesting that the simplified reporting process and anonymized near-miss functionality effectively removed the primary behavioral barriers identified in the literature.

5. Impact on OHS Incident Data

Comparison of official OHS records from the six months preceding and following application deployment revealed statistically and practically significant changes across all tracked incident categories, as presented in Table 5.

Table 5. Comparative OHS Incident Data: Six Months Pre- vs. Post-Implementation

Incident Category	Pre-impl. (6 mo.)	Post-impl. (6 mo.)	Change (%)
Minor Accidents	28	11	−60.7%
Moderate Accidents	9	4	−55.6%
Near-Miss Reports	14	43	+207.1%
Unsafe-condition reports	22	67	+204.5%
Average Safety Response Time	47 min	8 min	−83.0%

Source: PT. Semen Padang official OHS records (June–November 2023 vs. June–November 2024). Verified by authorized OHS management personnel.

The most salient finding is the 207.1% increase in near-miss reports and the 204.5% increase in unsafe-condition reports post-implementation. This increase should be interpreted not as a deterioration in workplace conditions, but as a direct manifestation of Heinrich's Triangle being made visible: the application enabled the reporting of previously undocumented leading indicators that had always existed but gone unrecorded. This interpretation is corroborated by the simultaneous 60.7% and 55.6% reductions in minor and moderate accidents, respectively, demonstrating that the newly captured near-miss data was acted upon through targeted corrective interventions.

The 83.0% reduction in average safety response time—from 47 minutes to 8 minutes—represents the most operationally critical outcome. For incidents involving chemical exposures, falls from height, or entrapment, this 39-minute reduction in response initiation time can mean the difference between a recoverable injury and a fatality or permanent disability.

DISCUSSION

The results of this study provide strong empirical support for the hypothesis that a well-designed mobile OHS reporting application, deployed with appropriate organizational support, can produce substantial improvements in safety reporting quality, user satisfaction, and actual workplace safety outcomes within a relatively short implementation period.

The 83.0% reduction in reporting time represents the most immediate and measurable operational benefit. This figure exceeds the 68% reduction reported by Zhang et al. (2021) in construction settings and the 71% figure reported by Liang et al. (2022), suggesting that the offline-first architecture and participatory design approach adopted in the present study contributed incrementally to performance beyond what has been previously achieved. The offline mode was activated in approximately 14.3% of all submitted reports, confirming its practical necessity in the PT. Semen Padang operational environment and validating the design decision to prioritize this feature.

The SUS improvement from 56.3 to 82.7 places the final system in the upper quartile of OHS mobile applications documented in the peer-reviewed literature (Lee & Kim, 2022; Permana & Widodo, 2023). The participatory design process, which involved three structured workshops with representative end-users prior to development, appears to have been a significant contributor to this outcome—aligning with the design principles advocated by Chen et al. (2023) as a prerequisite for high-impact OHS technology interventions.

The 207.1% increase in near-miss reporting is arguably the most strategically significant outcome for long-term safety management. Organizations with high near-miss reporting rates consistently demonstrate lower rates of serious injuries over multiple years (Hollnagel, 2014). The application's anonymous near-miss reporting feature was identified in post-implementation interviews as a key enabler: 67 of the 120 surveyed employees (55.8%) stated they had submitted at least one near-miss report that they would not have submitted under the previous system, citing ease of use and confidence in anonymity as primary motivators.

Several important limitations of this study should be acknowledged. First, the quasi-experimental design without a concurrent control group means that temporal confounds—such as concurrent safety training campaigns or seasonal variation in incident rates—cannot be fully excluded. However, the magnitude of observed changes, the statistical robustness of SUS comparisons, and the internally consistent pattern of results across all measured outcomes collectively support a causal interpretation. Second, the six-month post-implementation evaluation window may not be sufficient to capture full adoption plateau effects or potential behavioral regression. A longitudinal follow-up study at 18 and 36 months is planned. Third, the study was conducted at a single facility; generalizability to other industrial sectors (mining, oil and gas, petrochemicals) or smaller organizations with different resource profiles requires further validation.

CONCLUSIONS

This study successfully developed and validated a cross-platform mobile application for real-time OHS incident reporting in a large-scale manufacturing environment. The system demonstrated robust technical performance across all seven key performance indicators, including sub-5-second report submission, sub-5-second notification delivery, and a crash rate of 0.3%, confirming its reliability for mission-critical safety applications.

Deployment over a six-month period at PT. Semen Padang yielded statistically significant improvements in user satisfaction (SUS: 56.3 → 82.7, $p < 0.001$), reporting compliance (63.1% → 92.4%), and average safety response time (47 min → 8 min, −83.0%). Most critically, objective OHS records documented a 60.7% reduction in minor accidents and a 55.6% reduction in moderate accidents, accompanied by a 207.1% increase in near-miss reports—an evidence-based indicator of a maturing proactive safety culture.

The developed system addresses the specific technical and organizational gaps identified in the prior literature: cross-platform compatibility, offline functionality with automatic synchronization, severity-tiered notification escalation, and participatory design informed by frontline worker input. These features collectively constitute a replicable design blueprint for digital OHS transformation applicable to diverse industrial contexts.

Future research directions include: (1) integration of machine learning algorithms for predictive risk scoring based on accumulated incident data; (2) expansion of the system to include wearable sensor integration for real-time physiological monitoring of workers in high-risk zones; (3) interoperability with national OHS regulatory reporting systems; and (4) longitudinal evaluation of safety culture maturation indices over a 36-month post-implementation horizon.

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