Design of a Proactive Network Connection Incident Monitoring System Using an Android Mobile Application and the Design Thinking Methodology in Industrial Environments

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ABSTRACT

Within Industry 4.0 and the IT/OT convergence, continuous network connectivity monitoring is essential for operational continuity. According to Siemens/Senseye (2024), Fortune Global 500 companies lose approximately USD 1.4 trillion annually to unplanned downtime (11 % of revenues), with automotive plants facing costs of up to USD 2.3 million per hour. Manual or spreadsheet-based monitoring systems lack proactive notifications, scale poorly, and produce delayed alerts, increasing mean time to response (MTTR) and technical workload.

This study designs a proactive network connection incident monitoring system as a low-cost Android mobile application. The system registers and supervises IP addresses, generates automatic email notifications on failures (digital Andon functionality), and incorporates Poka-Yoke error-proofing elements. Development followed the Design Thinking methodology (Empathize, Define, Ideate, Prototype, and Test) to ensure usability and alignment with user needs. A PRISMA 2020 review of 20 studies (2016–2026) informed the design, highlighting the impact of IoT, edge computing, Design Thinking, and Lean principles.

Functional tests confirmed reliable generation of contextualized email alerts, correct IP validation, status visualization, and database operations. The economic analysis estimated a total cost of MXN 131,400, with an internal rate of return of 38.86 % and a payback period of 1 year and 9 months, confirming financial viability. The results show that a user-centered mobile solution combining structured logging, automatic alerts, and Lean principles can support the shift from reactive to proactive network incident management, particularly in industrial and SME environments.

Keywords: Industry 4.0, network monitoring, Design Thinking, Android application, Andon, Poka-Yoke, IT/OT, proactive management, SME

INTRODUCTION

Within the framework of Industry 4.0 and the IT/OT convergence, continuous monitoring of networks and device connectivity is essential to ensure the operational continuity of production processes. According to the Siemens/Senseye The True Cost of Downtime 2024 report, Fortune Global 500 companies lose approximately $1.4 trillion annually to unplanned downtime, equivalent to 11% of their revenues (up from 8% or $864 billion in 2019). In the automotive sector, the cost of one hour of downtime can reach $2.3 million (more than double the 2019 figure), while the cross-industry manufacturing average stands at around $260,000 per hour (Aberdeen Research) and a large plant can lose roughly $253 million per year.

These interruptions generate significant economic losses, production delays, and overload of support teams, as the lack of real-time visibility prevents early detection of failures (Olajiga et al., 2024; Siemens/Senseye, 2024). Recent studies document that intelligent monitoring systems based on IoT, data analysis, and automated alerts can reduce unplanned downtime by 35% to 50% within the first year of implementation, improve operational efficiency, and shorten response times (Senseye, 2022; predictive and remote monitoring reports,

2024–2026). In this context, mobile and low-cost implementation solutions emerge as viable alternatives to complement or replace traditional supervision approaches, especially for SMEs.

Monitoring systems based on manual tools or spreadsheets present important structural limitations: they block equipment operation while running, lack proactive notifications, do not scale adequately with a high number of IP addresses or assets, and generate late alerts. Nearly half of industrial companies report network problems at least once a month (Kaspersky-type reports), with recovery times frequently ranging from 1 to 5 hours.

These deficiencies translate into slow response times, greater workload for technical personnel, difficulty identifying failure patterns, and obstacles to continuous improvement (Wambua et al., 2025; studies on Lean methods in IT infrastructure monitoring, 2018). The absence of a reliable history and real-time visibility hinders informed decision-making and raises operational costs associated with unplanned stops (Senseye, 2022; Olajiga et al., 2024). Therefore, the development of a system that combines structured logging, automatic alerts, and trend analysis capabilities is justified to shift from reactive to proactive management.

The objective of this work is to design a network connection incident monitoring system through a mobile application developed in Android Studio, which allows registering and supervising IP addresses, generating automatic email notifications in case of failures (digital Andon-type functionality), and incorporating error-proofing elements (Poka-Yoke).

The development is carried out under the Design Thinking methodology, whose phases of empathize, define, ideate, prototype, and test ensure that the solution responds to the real needs of end users in terms of usability, response speed, and ease of operation (Zainal et al., 2024; Sánchez et al., 2022). This combination of a user-centered approach, mobile technologies, Lean principles, and IoT capabilities aims to optimize response times, improve incident traceability, and contribute to the continuity of operations in industrial environments.

LITERATURE REVIEW

The PRISMA 2020 guidelines (Page et al., 2021) were applied to identify, select, and synthesize evidence on network and connection incident monitoring systems in industrial or IT environments, with emphasis on IoT solutions, mobile applications, Design Thinking, and Lean principles. The search was conducted in Scopus, IEEE Xplore, ScienceDirect, and Google Scholar (2016–2026) using combinations of terms such as “network monitoring” OR “incident monitoring” OR “condition monitoring” AND (IoT OR “Design Thinking” OR Android OR Lean OR “mobile application”).

Approximately 1,200 records were identified; after removing duplicates and applying inclusion criteria (direct relevance to connectivity/incident monitoring, industrial or IT/OT context, publication since 2016, and availability of empirical or methodological results), 20 studies were selected for the main report.

Table 1 summarizes the 20 included articles. Each row captures the author/year, main focus, dominant methodology, and key findings relevant to the design of proactive monitoring systems.

Table 1. Report of 20 included articles (PRISMA synthesis)

#	Author / Year	Main focus	Methodology	Key findings
1	Xiao et al. (2024)	Condition monitoring networked plant-wide	Edge computing + networked control	Drastic reduction in inspection time (from hours to minutes) with algorithms deployed on edge nodes
2	Sánchez et al. (2022)	Condition monitoring with DT + Agile	Design Thinking + Agile (industrial case)	Successful implementation in 6 months; continuous feedback from key users for early failure detection
3	Olajiga et al. (2024)	Intelligent monitoring systems manufacturing	Systematic review	IMS based on IoT/AI/ML improve real-time visibility and failure prediction
4	Zainal et al.	Design Thinking in	Student study +	Improvement in understanding and

	(2024)	IoT projects	rubric	creativity; rubric score from 2.52 to 3.48
5	Tsallis et al. (2026)	Industrial wireless networks Industry 4.0	PRISMA review (60 studies)	Shift toward predictive approaches; gaps in interoperability and field validation
6	Yaseen (2025)	Programmable network-wide monitoring	Survey	Evolution from local counters to full network telemetry and observability
7	Aboubakar et al. (2022)	IoT Network Management	Review	Need for unified architectures for heterogeneous IoT network management
8	Kumar et al. (2026)	Deep learning IDS in IoT	PRISMA review + meta-analysis	DL models improve detection, but lack evidence of deployability at the edge
9	Misal (2024)	Automated monitoring IT infrastructure	Systematic analysis	Automated systems reduce detection time and downtime versus reactive approaches
10	Ahmad et al. (2022)	IoT monitoring milling process	Case study	IoT architecture enables parameter updating and real-time monitoring
11	Mourtzis et al. (2021)	IoT remote monitoring predictive maintenance	WSN + algorithms	Framework for remote monitoring of refrigeration systems and failure prediction
12	Fedullo et al. (2022)	Time-Sensitive Networks industrial	Review	TSN enables critical traffic in industrial networks for measurement and control
13	Islahudin et al. (2024)	Real-time production monitoring IoT	Implementation	Improved production agility and reduced downtime through real-time data
14	Liu et al. (2024)	Intelligent monitoring machinery deep learning	LSTM + anomaly detection	30% reduction in unplanned downtime; high accuracy in failure prediction
15	Val et al. (2024)	ML-enabled smart sensors industrial	Empirical analysis	5.5% improvement in uptime; positive ROI in energy and manufacturing sectors
16	Zainal / DT IoT (2024)	DT tools for IoT projects	Empirical evaluation	DT tools (POV, Affinity Diagram) improve requirements elicitation
17	Tricahyono & Ichwan (2024)	IoT smart tracking Design Thinking	Qualitative case	Ideation of more relevant cybersecurity features and predictive algorithms
18	Lean IT monitoring (2018)	Lean methods IT infrastructure monitoring	Case study	77% reduction in alerts and 49% in events; increase in monitored elements
19	Powell (2022)	Intelligent Poka-Yokes digital Lean	Conceptual + analysis	Intelligent Poka-Yokes with sensors and real-time feedback prevent errors
20	5G real-time monitoring review (2025)	5G impact on industrial monitoring	PRISMA review	5G reduces latency and improves synchronization in industrial monitoring and control

Table 1 shows a clear concentration of studies on condition monitoring and real-time monitoring based on IoT and edge computing (Xiao et al., 2024; Olajiga et al., 2024), together with the application of Design Thinking to align technological solutions with user needs (Sánchez et al., 2022; Zainal et al., 2024). Several works report measurable reductions in response times or downtime, supporting the transition from reactive or manual systems toward proactive approaches.

Table 2. Analysis of most used tools: frequency and impact

Tool / Approach	Frequency (approx. n/20)	%	Main reported impact
IoT / sensors + protocols (MQTT, OPC UA, Modbus)	14	70%	Real-time visibility, early failure detection, downtime reduction
Design Thinking (Empathize–Test phases)	7	35%	Better alignment with user needs, greater usability and adoption
Machine Learning / Deep Learning (LSTM, anomaly detection)	9	45%	Failure prediction, reduction of false positives, uptime improvement
Edge computing / distributed nodes	6	30%	Lower latency, local processing, resilience to disconnections
Mobile applications / Android	5	25%	Accessibility, push/email notifications, field use by technicians
Lean principles (digital Andon, Poka-Yoke)	4	20%	Immediate alerts, error prevention, reduction of unnecessary alerts
Traditional monitoring platforms (PRTG, Zabbix, Nagios)	6	30%	Broad IT/OT coverage, centralized dashboards, industrial support

Table 2 indicates that IoT and its associated protocols are the most frequent and highest-impact tools, enabling the shift from reactive to proactive monitoring and the integration of field data with management systems (Olajiga et al., 2024; Tsallis et al., 2026).

Design Thinking appears consistently when seeking to ensure usability and adoption, especially in the development of mobile applications or condition monitoring systems (Sánchez et al., 2022; Zainal et al., 2024). Machine Learning and edge computing approaches complement these solutions by improving predictive capability and latency, while Lean principles (Andon and Poka-Yoke) are reported as useful for structuring alerts and reducing operational noise.

Overall, the reviewed evidence supports the design of monitoring systems that combine a mobile application (Android), a local database, automatic notifications, and a user-centered development process through Design Thinking, incorporating Andon-type alert elements and error prevention. This allows addressing the limitations of manual or spreadsheet-based systems regarding response time and visibility.

METHODOLOGY

The present study is defined as a longitudinal mixed-methods investigation with a single-case experimental design, aimed at examining the effects of a continuous improvement intervention on fiscal and administrative productivity indicators in a real SME in the specialized engineering and construction sector. This type of design allows combining the analytical depth of a case study with the pre-post comparison of quantitative variables, which is particularly suitable in SME contexts where multi-site controlled experiments are frequently unfeasible due to resource limitations and organizational access constraints (Creswell & Creswell, 2018; Yin, 2018).

The independent variable corresponds to the continuous improvement intervention based on Kaizen principles and the PDCA cycle (Plan-Do-Check-Act), implemented through low-cost tools. The dependent variables are operationalized through five indicators: (1) cycle time for worker registration with the IMSS (days), (2) documentation error rate (errors per week), (3) percentage of complete files (%), (4) file location efficiency (average minutes), and (5) timely release rate of guarantee funds (%). The unit of analysis is a single specialized engineering and construction SME, selected for its representativeness in the Hidalgo context and for the possibility of prolonged access to data and processes, enabling longitudinal follow-up of 8 to 12 months (Stake, 1995; Flyvbjerg, 2006).

The methodological approach is predominantly applied and pragmatic, with priority given to open and low-cost tools (Excel, Google Sheets, printed templates, Google Drive, and free statistical software such as R or

Python), with the purpose of favoring replicability in other construction and engineering SMEs in Mexico (Singh & Singh, 2019; García-Sabater et al., 2021).

A sequential exploratory mixed-methods approach is adopted, in which quantitative baseline and post-intervention data are complemented with qualitative data obtained through interviews, observation, and thematic analysis, allowing both the measurement of effects and the understanding of facilitators and barriers to implementation (Ivankova et al., 2006; Creswell & Plano Clark, 2018).

The intervention is structured in six sequential phases aligned with the PDCA cycle, adapted from continuous improvement implementation frameworks in SMEs (Imai, 2012; Liker & Franz, 2011; Suárez-Barraza & Ramis-Pujol, 2010).

Phase 1 – Diagnosis (2–4 weeks)

This phase aims to establish a robust baseline and identify the root causes of inefficiencies. A 12-month period of historical records of the five dependent indicators is analyzed from internal systems, IMSS reports, and SAT reports. Swimlane flow diagrams of the priority processes (IMSS worker registration and guarantee fund administration) are prepared. Semi-structured interviews and surveys are conducted with 10 to 15 key actors (human resources, administrative staff, and project managers), using a guide based on the 6M categories. An Ishikawa diagram is developed in a participatory workshop, and baseline KPIs are documented using descriptive statistics (mean, median, standard deviation, or interquartile range) and a Pareto diagram for problem prioritization (Ishikawa, 1985; Montgomery, 2019).

Phase 2 – Process redesign and prioritization (2–3 weeks)

Workflows are redesigned with emphasis on standardization, visual management, and checklists, eliminating non-value-adding steps. A prioritization matrix (impact versus ease of implementation, scale of 1 to 5) is applied to select high-impact and low-cost actions. Standard operating procedures (SOPs) and SMART goals are defined (for example: registration time $\leq$ 1 day, errors $\leq$ 1 per week, complete files $\geq$ 90%, and location $\leq$ 5 minutes). Open and low-cost tools are selected, and participatory validation is carried out with key actors (Womack & Jones, 2003; Imai, 2012).

Phase 3 – Capacity development (2–4 weeks)

Between 15% and 25% of the relevant administrative and human resources staff are trained in Kaizen principles, the PDCA cycle, Ishikawa analysis, 5S (physical and digital), and standardized procedures, through 8- to 16-hour workshops with practical application. SOPs and operational manuals are documented to ensure knowledge transfer. Learning is evaluated through pre-post questionnaires, and feedback is collected, with the purpose of building operational autonomy and reducing dependence on external consultants (Liker & Franz, 2011; Suárez-Barraza et al., 2011).

Phase 4 – Pilot implementation (4–6 months)

This constitutes the longest and most critical phase. Standardized processes are executed (checklists, visual management, and physical and digital 5S of documents). Internal fiscal and operational audits are conducted weekly or biweekly, together with systematic cross-validation between IMSS, SAT, and internal system records. KPIs are monitored weekly through dashboards (Excel, Google Sheets, or light Power BI) and run charts or control charts. Micro-PDCA cycles are applied for iterative adjustments, risk premium classification in IMSS is corrected when identified, and an incident log and improvement log are maintained (Deming, 1986; Montgomery, 2019).

Phase 5 – Evaluation and refinement (2–4 weeks)

Pre- and post-implementation indicators are compared through absolute and percentage changes. For continuous variables, a normality test is performed (Shapiro-Wilk or Kolmogorov-Smirnov); if the assumption

is met, a paired t-test is applied, and otherwise the Wilcoxon signed-rank test. Mean or median, standard deviation or interquartile range, absolute and percentage change, p-value, and 95% confidence interval are reported. For rates and proportions, appropriate tests are used (Wilcoxon, McNemar, or difference of proportions). Effect size is calculated (Cohen's d or Wilcoxon r) to assess practical magnitude. This is complemented with qualitative analysis through follow-up interviews, observations, and thematic analysis (Braun & Clarke, 2006; Creswell & Plano Clark, 2018). Methodological triangulation of quantitative, qualitative, and multiple sources is performed.

Phase 6 – Scaling and sustainability

Successful workflows are integrated into the company's standard operations, permanent KPI monitoring is established through a control dashboard, and recommendations are formulated for the institutionalization of periodic audits, continuous training, and Kaizen culture. Results are prepared for possible dissemination in regional SME networks in Hidalgo and academic forums. Success criteria include the achievement or significant approximation of SMART goals, evidence of staff autonomy, and initial indications of sustainability (Imai, 2012; Singh & Singh, 2019).

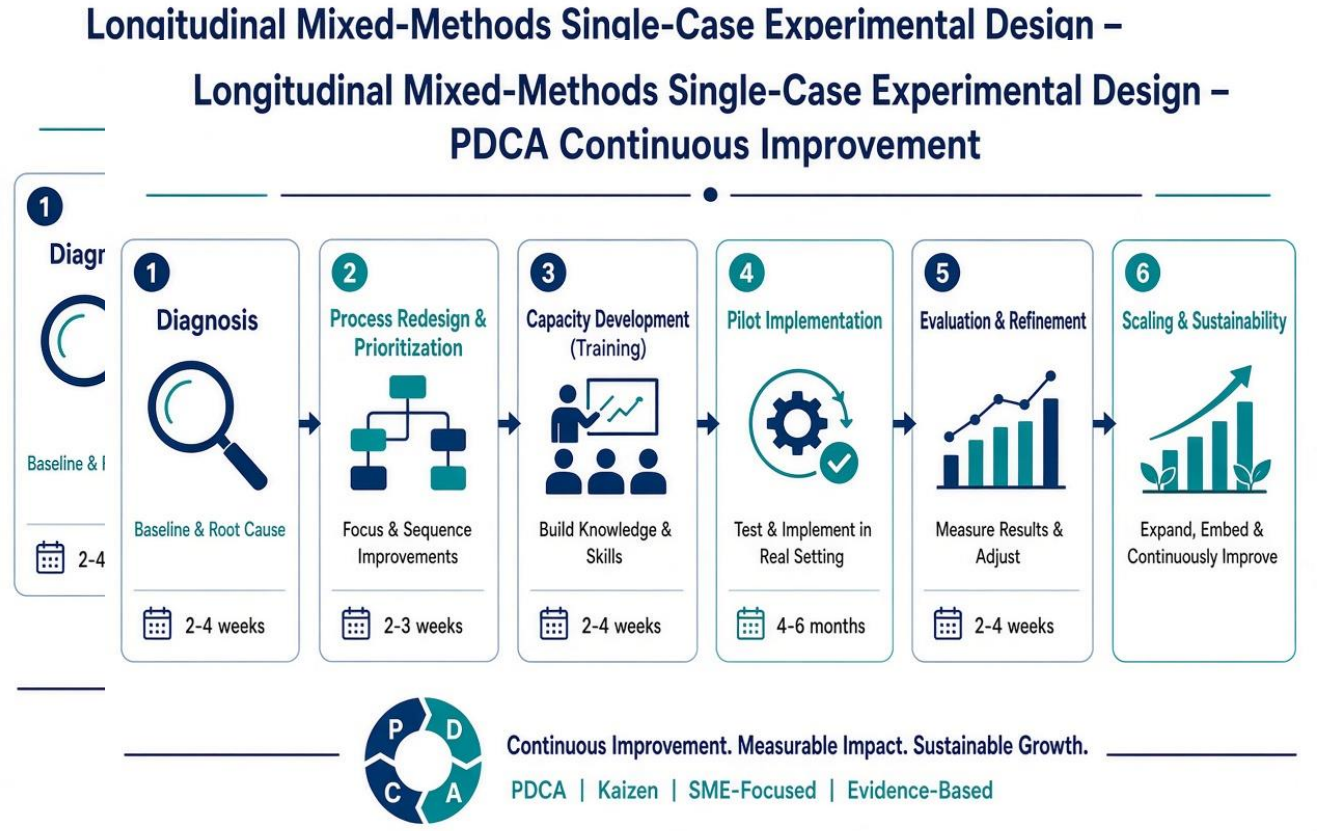


Figure 1. Methodology Overview (Single-Case Experimental Design – Continuous Improvement in an SME)

This study uses a longitudinal mixed-methods single-case experimental design to evaluate the impact of a Kaizen/PDCA continuous improvement intervention on five fiscal and administrative productivity indicators in one specialized engineering and construction SME in Hidalgo, Mexico. The intervention is implemented over 8–12 months through six sequential phases diagnosis (baseline and root-cause analysis), process redesign and prioritization, capacity development (training), pilot implementation, evaluation and refinement (pre-post quantitative analysis plus qualitative triangulation), and scaling with sustainability measures using low-cost tools to ensure practicality and replicability. The design combines the depth of a case study with pre-post comparisons, emphasizing practical significance, process transparency, and mixed-methods triangulation while addressing the typical resource constraints of SMEs.

Data analysis

The analysis integrates descriptive and inferential statistics (paired tests according to normality and effect sizes) with qualitative thematic analysis. Low-cost and accessible software is prioritized (Excel, Google Sheets, R or Python with scipy and pandas). Given the case study nature, practical significance and temporal trend analysis are emphasized over isolated statistical significance (Field, 2018; Yin, 2018).

Validity, reliability, ethics, and limitations

Internal validity is supported by the pre-post design, triangulation of methods and sources, the detailed audit trail, and control through SOPs. External validity and replicability are favored through an explicit protocol and the use of low-cost tools. Reliability is reinforced with documented SOPs, standardized training, and instrument validation. In ethical matters, informed consent from the company and staff, anonymization of sensitive data (IMSS, fiscal, and business), and confidentiality are contemplated. The main limitations are the single case (limited generalization), the possible Hawthorne effect, and dependence on the commitment of key personnel; these are mitigated through analytical depth, triangulation, and protocol transparency (Yin, 2018; Creswell & Plano Clark, 2018).

RESULTS

Empathize Phase

In this phase, the needs and frustrations of the key user in the systems area were identified. The main finding was the dependence on manual monitoring in spreadsheets, which generated delays in the detection and notification of connection failures, increasing the mean time to response (MTTR) and affecting operational continuity. The empathy map showed that the user needed to receive immediate and contextualized alerts, but the existing system did not allow this in a proactive manner.

Table 3. Main findings of the Empathize phase

Aspect	Main result	Implication
Current monitoring method	Manual recording in spreadsheet	High dependence on staff and delays in detection
Priority need	Immediate and contextual notifications of IP failures	Reduction of MTTR and improvement of proactivity
Main frustration	Constant manual verification and lack of automatic alerts	Increase in response time to incidents

Define Phase

Based on the empathy map, an insight was developed that synthesized the central problem: the lack of reliability of the manual monitoring system prevented acting proactively, generating a high MTTR and loss of credibility of the systems area. “How might we?” questions were formulated, oriented toward real-time notifications, complete context of the failure, and compatibility with security restrictions.

Table 4. Defined insight (adapted from the document)

User	Need	Insight
Systems / networks staff	Receive immediate and contextual notifications of connection failures	The lack of reliability of the current system prevents being proactive, raising MTTR and affecting operational continuity

Ideate Phase

Through brainstorming, prioritized ideas were generated. The most relevant were: automatic email alert system, inclusion of complete failure context (IP, location, type of error), and an accessible visual status dashboard. These ideas were consolidated into an action plan that contemplates system implementation, continuous monitoring, updating of the control log, and staff training.

Table 5. Prioritized ideas (brainstorming) and action plan

Idea / Activity	Description	Estimated duration
Real-time automatic alerts	Email notification when an IP goes offline	Included in development
Failure context	Inclusion of name, location, and type of error in the alert	Included in development
Status dashboard	Visualization of the status of monitored IPs	Included in development
Control log	Structured recording of critical incidents	Permanent
Staff training	Training in the use of the new system	2–3 months

Prototype Phase

The mobile application was developed in Android Studio (Java language) with a local SQLite database. The application has home, IP check, IP address edit/registration, and monitoring screens. The main functionalities include IP registration and deletion, format validation, and periodic verification of connectivity status.

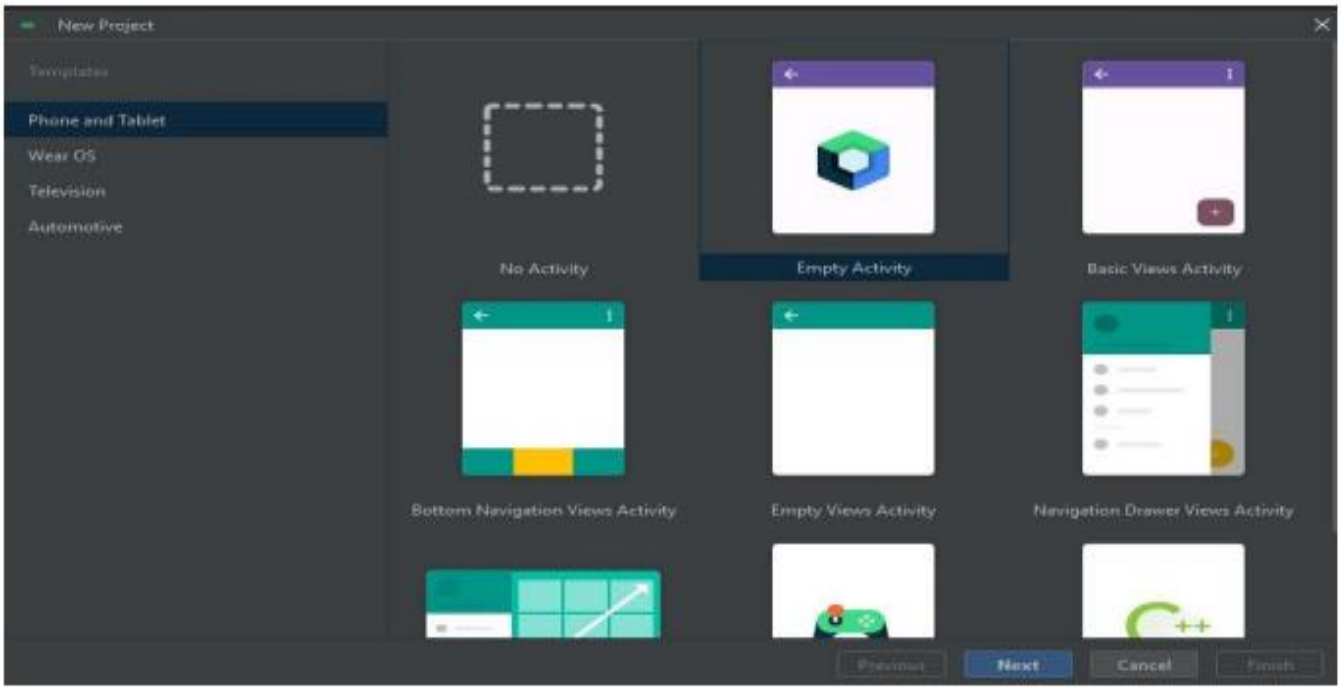


Figure 2. Project screen in Android Studio

Test Phase

Failure simulation tests and verification of the status of registered IPs were carried out. The system correctly generated email notifications when an IP was offline, confirming the alert functionality.

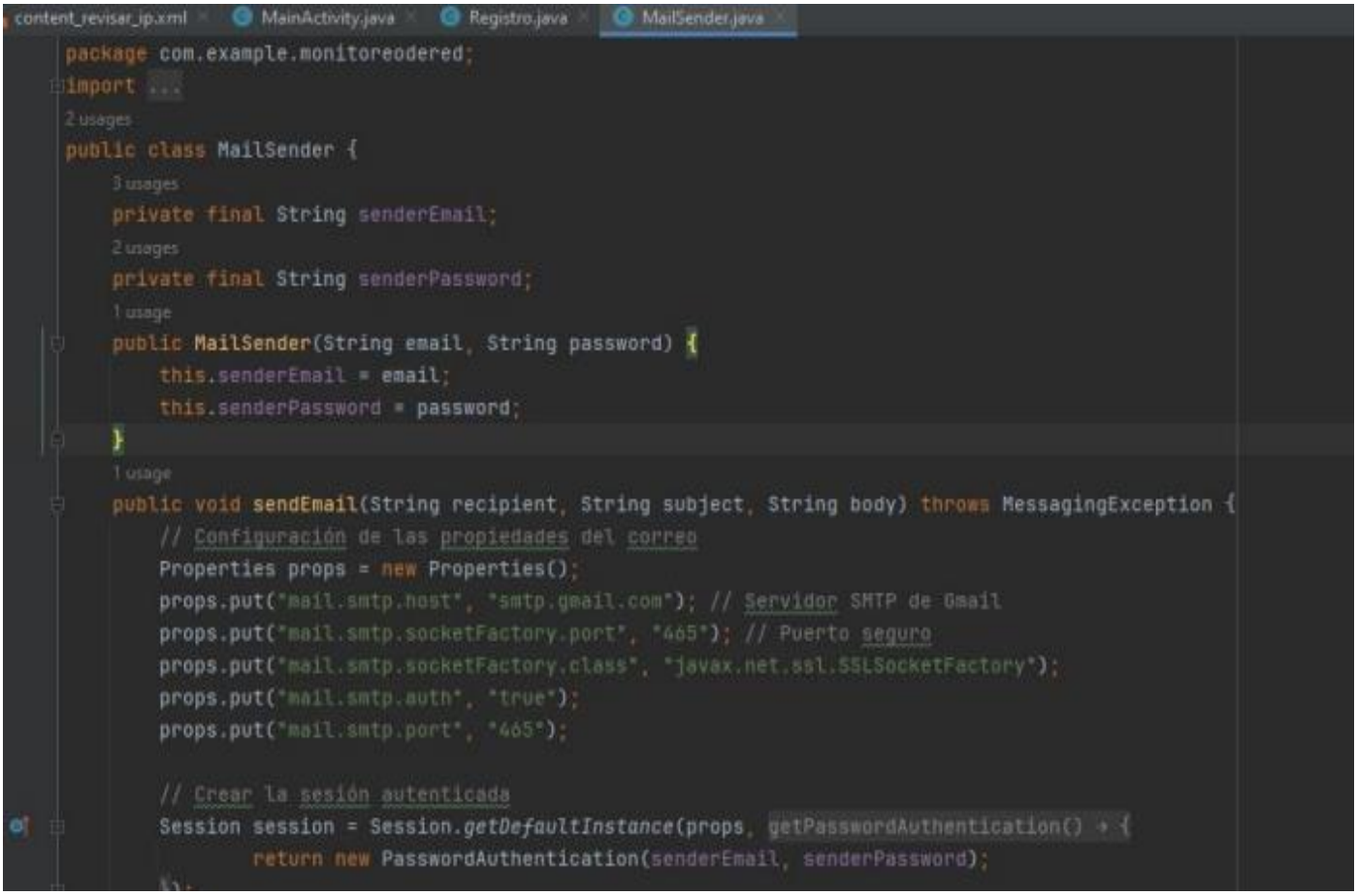


Figure 3. Scheduling email notifications

Table 6. Results of the functionality tests

Test performed	Result	Observation
Offline IP simulation	Email alert generated	Notification received with failure context
IP registration and validation	Acceptance of valid IPs and rejection of duplicates or incorrect format	Error control functionality operational
Status visualization	List of IPs with current status	Monitoring interface operational
IP deletion	Correct deletion of records	Database management functional

Economic Feasibility Results

The financial analysis estimated a total development and implementation cost of $131,400 MXN. The component with the greatest weight was specialized labor (82.65%). The three-year cash flow analysis showed an IRR of 38.86% and an investment recovery period of 1 year and 9 months, confirming the financial viability of the project.

Table 7. Summary of costs and financial viability (adapted)

Concept	Amount (MXN)	% of total
Development (labor)	108,600	82.65%
Hardware / Software	11,300	8.60%

Indirect costs	11,500	8.75%
Total cost	131,400	100%
IRR	38.86%	—
Payback period	1 year 9 months	—

CONCLUSION

This work demonstrates the feasibility and practical value of designing a proactive network connection incident monitoring system through a mobile Android application developed under the Design Thinking methodology in industrial environments. The combination of a user-centered approach, low-cost mobile technology, structured data logging, automatic notifications, and Lean principles (digital Andon and Poka-Yoke) addresses the principal limitations of traditional manual or spreadsheet-based monitoring systems, namely delayed detection, lack of contextual information, limited scalability, and high dependence on constant human verification.

The application of Design Thinking proved effective in aligning the technological solution with the actual needs of systems and network personnel. The Empathize phase revealed the critical frustration caused by the absence of immediate, contextualized alerts and the consequent elevation of mean time to response (MTTR). The Define phase synthesized this problem into a clear insight, while the Ideate phase prioritized automatic email notifications containing failure context (IP, location, and error type), a visual status dashboard, and a structured incident log.

The Prototype phase resulted in a functional Android application built in Android Studio with a local SQLite database, supporting IP registration, format validation, periodic connectivity checks, and monitoring screens. The Test phase confirmed that the system correctly generates email alerts when an IP goes offline and properly manages registration, validation, visualization, and deletion operations.

These functional outcomes are consistent with the evidence synthesized in the PRISMA review of 20 studies. The literature shows a clear concentration on IoT- and edge-computing-based condition monitoring, the value of Design Thinking for improving usability and adoption, and the contribution of Lean principles to alert structuring and error prevention. The present solution operationalizes several of these findings in a mobile, low-cost format suitable for industrial settings and SMEs.

The economic analysis further supports the practical relevance of the proposal. With a total estimated cost of MXN 131,400 and an IRR of 38.86 % over a three-year horizon, the project demonstrates financial viability and a payback period of 1 year and 9 months. Given the high hourly costs of unplanned downtime documented in the literature (ranging from tens of thousands to millions of dollars depending on the sector), even modest reductions in response time or avoided incidents can generate returns that justify the investment.

Nevertheless, several limitations should be acknowledged. The study focuses on design, prototyping, and functional testing rather than a prolonged industrial deployment with measured operational impact (e.g., quantified reduction in MTTR or number of incidents). Generalization is constrained by the single-context development process.

Future work should include extended field testing in real industrial environments, integration with additional notification channels or lightweight dashboards, exploration of edge-computing or machine-learning enhancements for anomaly detection, and multi-site validation to assess scalability and sustainability. Longitudinal studies examining user adoption, training requirements, and the interaction between the mobile system and existing IT/OT infrastructures would also strengthen the evidence base.

In summary, the proposed system constitutes a viable, user-centered, and financially attractive alternative for improving the proactivity and traceability of network incident management in industrial environments. By combining Design Thinking, mobile technology, and Lean principles, it offers a practical pathway for organizations particularly SMEs to move from reactive supervision toward continuous, real-time visibility and faster response, thereby contributing to operational continuity under Industry 4.0 conditions.

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