QUALITATIVE FRAMEWORK FOR AI AND IOT IN INDUSTRY 5.0

New Trends in Qualitative Research

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ABSTRACT

With particular emphasis on human-centered automation and sustainability, this study qualitatively examines the role of artificial intelligence and the Internet of Things within the Industry 5.0 framework. Unlike Industry 4.0, which primarily emphasized automation and operational efficiency, Industry 5.0 promotes collaborative intelligence by integrating human capabilities with AI-supported decision-making and real-time monitoring. The study aims to identify the distinctive characteristics of Industry 5.0 and examine how emerging technologies are reshaping the relationship between human labor and automation while contributing to efficiency, resilience, safety, and sustainability in industrial environments. Methodologically, the research combines a systematic literature review with bibliometric analysis to identify central thematic axes, conceptual relationships, and emerging trends associated with the integration of AI and IoT in industrial process optimization. This combined approach supports a qualitative interpretation of technological, organizational, ethical, and human-centered dimensions that might remain fragmented if examined exclusively through technical or quantitative perspectives. The analysis identified eight conceptual categories, sixteen theoretical links, and twenty-eight emerging themes related to human-machine collaboration, digital competencies, ethical AI governance, workforce development, real-time monitoring, and sustainable industrial practices. The methodological contribution lies in the integration of qualitative thematic interpretation and bibliometric mapping within a coherent analytical framework for examining complex technological transformations. This approach provides a structured means of connecting conceptual patterns in the literature with broader questions concerning human agency, responsible automation, and sustainability. The findings indicate that Industry 5.0 requires not only advanced technologies but also methodological approaches capable of interpreting the social, ethical, and organizational implications of their implementation. The proposed framework therefore contributes to qualitative research by offering a transferable analytical structure for studying human-technology relationships in industrial contexts while preserving attention to contextual complexity, interpretive depth, and human-centered values.

Keywords
Industrial optimization; Industry 5.0; Artificial Intelligence (AI); Internet of Things (IoT); Digital transformation.

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1. Introduction

Organizational structures, industrial production, and the interaction between human labor and technical systems are all changing as a result of digital transformation. In this regard, Industry 5.0 expands on the goals of Industry 4.0 by stressing resilience, sustainability, and human-centeredness. Rather than focusing exclusively on automation and operational efficiency, Industry 5.0 seeks to integrate the analytical capabilities of artificial intelligence (AI) and the Internet of Things (IoT) with human judgment, creativity, and adaptability.

By coordinating technical advancements with worker skills, organizational requirements, and more general social and environmental goals, Industry 5.0 fosters human-centric smart production. This viewpoint acknowledges that the deployment of AI and IoT has ethical, organizational, cultural, and workforce-related ramifications, making it impossible to fully explain industrial change using technological performance metrics alone. As a result, human-machine cooperation becomes crucial, especially when it comes to decision-making, workplace safety, professional competences, responsible automation, and maintaining human agency (Zhang et al., 2023). Its convergence with Society 5.0, Marketing 5.0, and Education 5.0 further demonstrates how technological change impacts social participation, workforce development, and institutional practices in addition to manufacturing (Bakator et al., 2024). IoT and AI-enabled solutions provide data-driven decision-making, process optimization, predictive maintenance, and real-time monitoring. Intelligent robots, digital twins, mobile apps, and networked systems may enhance worker-technological infrastructure interaction. Concerns like data governance, transparency, digital competences, organizational adaption, and the distribution of technology advantages are also raised by their deployment. The technical performance of AI and IoT in industrial optimization has been well studied in the past, but the literature on their consequences for people, ethics, organizations, and sustainability is still dispersed. Understanding how these factors interact within the human-centered concepts of Industry 5.0 is limited since technological efficiency, resource allocation, automation, and predictive analytics are often discussed independently. Because qualitative research allows for the analysis of meanings, experiences, contextual conditions, and interpretive relationships that cannot be reduced to quantitative indicators, it is especially suitable for filling this gap. Additionally, it facilitates the integration of diverse evidence, such as academic literature, expert viewpoints, documentary materials, and visual data. To achieve the human-centered, resilient, and sustainable objectives of Industry 5.0, this research looks at how AI and IoT support industrial process optimization. Using a qualitative approach that incorporates a thorough literature review, bibliometric mapping, thematic interpretation, expert interviews, and data triangulation, it determines the main conceptual categories, theoretical connections, and emergent themes related to this shift. The integration of bibliometric mapping with qualitative topic analysis and triangulated evidence is the methodological contribution. The research employs bibliometric data to enhance the understanding of conceptual linkages, methodological gaps, and human-centered issues rather than considering them as independent indicators.

This method offers a methodical framework for analyzing industrial transformation as a sociotechnical process and might guide qualitative research on human-technology interaction in other industries that have undergone digital transformation.

2. Literature Review

The change from Industry 4.0 to Industry 5.0 signifies a move toward an industrial paradigm that is human-centered, sustainable, and adaptable. Industry 5.0, in contrast to its automation-driven predecessor, combines artificial intelligence, human intelligence, and the Internet of Things (IoT) to enhance process optimization and decision-making (Sindhwani et al., 2022). Real-time monitoring, predictive analytics, and smart automation improve operational flexibility and highlight the significance of IoT in networked industrial systems (Zrelli & Rejeb, 2024). Internet-oriented, things-oriented, and semantic-oriented layers are often found in IoT designs. These layers facilitate data processing, smart-device interaction, and data transfer, improving coordination between digital and physical systems (Pandey et al., 2023).

2.1 Theoretical Foundations of Industry 5.0 and Industrial Optimization

Industry 5.0 is based on sociotechnical viewpoints that strike a balance between significant human involvement and technological advancement. According to this perspective, workers continue to play a crucial role in production, and technology facilitates judgment, flexibility, and decision-making. Therefore, organizational structures, workforce flexibility, social and cultural circumstances, and technological performance are all important factors in how well AI integration works. Hospital incident-reporting systems have shown similar trends, with results heavily influenced by social dynamics and organizational culture (Tresfon et al., 2025). Industry 5.0 encourages responsible automation, ethical AI, and digital sustainability by framing IoT and AI as decision-support tools rather than labor replacements. Reinforcement Powered by Decision Trees In order to assist automation that supports human duties, learning has been investigated for computational offloading and resource allocation in Internet of Things applications (Walia & Kumar, 2025). This viewpoint is also consistent with Education 5.0, which highlights the use of technology to promote fair access to information and human growth.

2.2 AI and IoT in Industry 5.0: Key Drivers of Industrial Process Optimization

In industrial settings, AI and IoT facilitate decision-making, predictive analytics, and real-time monitoring. Predictive maintenance based on machine learning may improve process efficiency by lowering operating costs and breakdowns (Xu et al., 2025). In industrial systems, IoT-enabled ecosystems promote sustainability, flexibility, and dynamic data sharing (Hu et al., 2025). Supply chain resilience also benefits from these technologies.

In complex environments, AI-IoT prediction models may help with operational continuity, interruption detection, and adaptive decision-making (Sudan et al., 2023).

Smart automation, when included into supply chain management, helps improve recovery plans in times of unpredictability and quick change.

2.3 AI-Driven Industrial Automation

By enhancing resilience, cutting waste, and boosting quality control, artificial intelligence is revolutionizing industrial processes (El Jaouhari et al., 2023). High-quality data and dependable computing infrastructure are necessary for these advantages.

AI-driven automation in Industry 5.0 is becoming more closely linked to sustainability, especially waste reduction and resource optimization (Darzi, 2025). Adaptive optimization and predictive decision-making may help industrial processes become more ecologically conscious (Pilbeam et al., 2025). However, how AI systems are created, managed, and incorporated into business procedures will determine these advantages.

2.4 The Role of IoT in Industrial Process Optimization

Through remote monitoring, real-time analysis, and independent decision-making, IoT allows intelligent and networked industrial systems. IoT helps businesses react to market shifts and supply chain disruptions by increasing agility and flexibility. By keeping an eye on working conditions and spotting operational hazards, it can also improve occupational health and safety (Gonçalves et al., 2025). Through resource allocation, predictive maintenance, and ongoing monitoring, IoT promotes sustainability and energy efficiency. Its incorporation with AI enhances Industry 5.0 systems' ability to become more robust, adaptable, and sustainable. IoT-based safety systems further highlight the significance of data-driven choices for lowering risks and enhancing operational resilience in high-risk industries (Misra et al., 2025).

2.5 Human-Centric Digital Transformation in Industry 5.0

Human-machine cooperation, where AI-supported technologies help workers rather than replace them, is a key component of Industry 5.0. The Factories-of-the-Future model, which blends human expertise with cutting-edge digital technology, reflects this idea (Adel et al., 2024). Softwarization and servitization facilitate ecosystems that are adaptable, scalable, and service-oriented. By enabling coordinated interaction between workers and intelligent systems, the convergence of AI, cloud-native architectures, and network virtualization enhances sustainability, resilience, and adaptability. Additionally, Industry 5.0 promotes a shift to service-oriented models where technology supplements human labor (Hliš et al., 2024).

2.5.1. Ethical AI and Responsible Automation

Transparency, equity, accountability, and significant human monitoring are necessary for the ethical use of automation. Ethical AI is becoming more closely associated with sustainable practices in Industry 5.0, especially in green supply chain management (Amin et al., 2025).

While maintaining data privacy, collaborative and distributed learning models may enhance AI-supported automation. Intelligent monitoring systems and cooperative robots are examples of technologies that might encourage resource efficiency and ecologically conscious choices. These advancements need governance frameworks that guarantee automation advances environmental and human objectives rather than escalating already-existing hazards or disparities.

2.5.2. Workforce Empowerment and Skill Development

Human-computer interaction, IoT, artificial intelligence, and digitally mediated decision-making skills are necessary for Industry 5.0. The focus of Education 5.0 research is on strategic training that bridges the gap between human comprehension and technology advancement (Destouet et al., 2023). The reintegration of human skills into sophisticated production systems is shown in flexible job shop scheduling and associated human-in-the-loop techniques. These models place a strong emphasis on skill development, worker well-being, and adaptation as prerequisites for sustainability and efficiency (Rasouli et al., 2025).

2.5.3. AI and IoT for Enhanced Workplace Safety

Through proactive risk identification and ongoing operational condition evaluation, AI-enabled safety systems backed by IoT-based real-time monitoring may enhance workplace safety. Within Industry 5.0's human-centered tenets, these technologies promote efficiency and safety.

The analysis of stress patterns, job design, human-machine interaction, and psychosocial workplace dynamics may also benefit from large language models. Data quality, analytical openness, and ethical governance are what determine their worth. They might promote safer and more context-sensitive industrial settings when used properly (Grybauskas & Cárdenas-Rubio, 2024).

3. Methodology

This empirical study with methodological reflection investigates the ways in which mobile applications, the Internet of Things (IoT), and artificial intelligence (AI) support Industry 5.0 industrial process optimization. The technical, organizational, ethical, and human-centered aspects of this change were examined using a qualitative design. The methodological approach included data triangulation, semi-structured expert interviews, documentary and visual analysis, bibliometric analysis, and a systematic evaluation of the literature. While maintaining the contextual richness necessary to study human-technology interaction in industrial contexts, this integration facilitated the discovery of conceptual patterns, theoretical connections, and emergent themes.

3.1 Research Design

The research was based on a qualitative sociotechnical approach, which views industrial change as the interplay of human agency, organizational contexts, technology systems, and ethical ideals. The examination took into account the ontological, axiological, and philosophical aspects of IoT and AI-enabled technologies, with a focus on their implications for human-machine cooperation, sustainability, safety, and responsible automation. Instead of conducting an experimental evaluation of these technologies, the study used a variety of qualitative sources to interpret their applications and conceptual relationships. In the theoretical framework of data integration, dynamic process management, and coordinated human-technology interaction, synchronized digital twins were taken into consideration (Jiang et al., 2024). The design linked expert viewpoints, factual and visual evidence from industrial environments, and patterns found in scientific literature.

3.2 Study Stages

3.2.1. Systematic Literature Review

Google Scholar, Web of Science, and Scopus were used to conduct a systematic literature review. Industry 5.0, AI, IoT, mobile apps, industrial optimization, human-machine cooperation, and sustainability were the main topics of the search, which included research published between 2015 and 2024.

In line with the sustainable and human-centered tenets of Industry 5.0, the review gave priority to conceptual, methodological, and practical contributions. To find recurrent ideas, theoretical stances, technical applications, and research needs, the chosen papers were qualitatively analyzed. Real-time monitoring, predictive maintenance, anomaly detection, energy efficiency, decision assistance, and human-technology interaction received special emphasis (Alijoyo, 2024).

3.2.2. Bibliometric Analysis

To map research trends, keyword co-occurrences, conceptual linkages, and thematic connections across the literature on Industry 5.0, AI, IoT, Marketing 5.0, and Society 5.0, bibliometric analysis was carried out using Bibliometrix in R and VOSviewer.

Based on their applicability to AI-IoT integration, industrial optimization, human-centeredness, sustainability, ethics, and organizational change, a selection of 48 papers was chosen. Rather than being treated as independent quantitative findings, the bibliometric data were interpreted within the broader qualitative analytical framework. This method facilitated the investigation of connections between human development, ethical governance, technical innovation, and industrial competitiveness (Bakator et al., 2024).

3.2.3. Semi-Structured Expert Interviews

Semi-structured interviews provided expert viewpoints on the deployment of AI, IoT, and mobile apps to supplement the literature-based investigation. Fifteen individuals with expertise in Industry 5.0, digital transformation, industrial innovation, AI-IoT deployment, or similar topics participated in the research.

Purposive sampling was used to choose participants based on their involvement in pertinent organizational or technological processes and professional experience. The interviews focused on workforce development, ethical AI governance, human-machine cooperation, process optimization, workplace safety, and sustainability. Rather than being statistically representative stories, the comments were considered contextual evidence.

3.2.4. Documentary and Visual Data Analysis

To determine how AI and IoT-enabled technologies are portrayed and used in operational settings, documentary and visual materials from industrial contexts were analyzed. The documentary study included organizational problems, workforce capabilities, sustainability, process optimization, and technology deployment.

Applications including intelligent automation, linked industrial systems, predictive maintenance, and real-time monitoring were contextualized using visual elements. By demonstrating the use of Industry 5.0 concepts, these sources enhanced the literature review and expert interviews.

3.2.5. Qualitative Thematic and Narrative Analysis

The research looked for patterns in literature, interviews, records, and visual data using theme and narrative analysis. Thematic analysis revealed recurrent themes pertaining to sustainability, digital competences, ethical AI, human-machine cooperation, industrial efficiency, and workplace change. The interpretation of how organizational adaptability, technological development, and human engagement were portrayed across sources was aided by narrative analysis. The materials were arranged, coding was managed, patterns were compared, and analytical consistency was maintained using NVivo 14. In contrast, fewer studies address the organizational, ethical, and human implications of AI-IoT integration.

3.2.6. Data Triangulation

Expert interviews, bibliometric analysis, documentary and visual materials, and a comprehensive literature review were all incorporated into data triangulation. Expert interviews offered professional interpretations, documentary and visual evidence contextualized industrial implementation, bibliometric analysis mapped conceptual trends, and the literature study formed the theoretical framework.

Triangulation allowed for deeper interpretation, cross-source comparison, and the identification of convergence and divergence. Additionally, it promoted a more comprehensive understanding of Industry 5.0 as a technological, organizational, and sociotechnical reality and reduced reliance on a single kind of proof.

3.3 Analytical Rigor and Intercoder Agreement

Using NVivo 14, two separate researchers applied the narrative and thematic codes to a representative sample. Cohen's Kappa was used to evaluate intercoder agreement, yielding a score of $\kappa = 0.79$, indicating significant agreement (McHugh, 2012).

Iterative discussion was used to address coding differences, and the codebook was updated when definitions or criteria needed to be clarified. Along with triangulation, clear coding practices, cross-source comparison, and cooperative assessment of analytical choices, intercoder agreement was considered one aspect of methodological rigor. These procedures promoted a consensus-based assessment of the data and reduced the impact of isolated opinions (Campbell et al., 2013).

3.4 Analytical Objectives and Validation

The goal of the investigation was to pinpoint the key ideas, thematic groups, theoretical connections, and new trends that AI and IoT use to optimize industrial processes. Technological efficiency, human agency, ethical governance, workforce development, workplace safety, resilience, and sustainability received special attention. Expert opinions, bibliometric trends, documentary and visual evidence, and triangulation throughout the literature all contributed to the conclusions' believability. The contextual and useful interpretation of the detected themes was further bolstered by expert comments. This approach supported the creation of a qualitative framework based on several sources

4. Results

The results demonstrate how mobile apps, the Internet of Things (IoT), and artificial intelligence (AI) are portrayed in the literature and understood by experts as industrial process improvement techniques within Industry 5.0. The findings are arranged in accordance with the study's primary analytical components, and their more comprehensive interpretation is provided in the discussion.

4.1 Systematic Literature Review

120 peer-reviewed papers published between 2015 and 2024 were kept for qualitative analysis after duplicates were eliminated and publications that did not fit the relevant criteria were eliminated.

The contributions of the research to AI, IoT, mobile applications, sustainability, human-machine cooperation, and industrial process optimization were categorized.

According to the study, the majority of research focuses on sustainable manufacturing, real-time monitoring, predictive maintenance, and technical efficiency. The organizational, ethical, and human consequences of AI-IoT integration, on the other hand, are the subject of fewer research. This disparity suggests that worker involvement, responsible automation, and human agency have received less attention as the technological aspects of Industry 5.0. The citation distribution of the 120 chosen papers is shown in Figure 1, which contrasts the observed pattern with Weibull, logistic, normal, and exponential distributions.

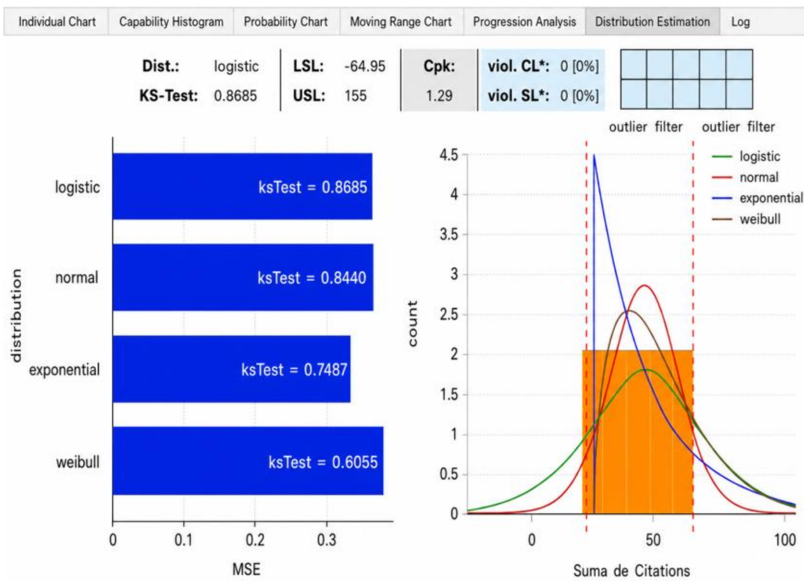

Figure 1. Estimation of Distributions for the Sum of Citations of Relevant Articles in Industry 5.0

Source: Author

The distribution of citations demonstrates the concentration of scholarly impact in the chosen literature. The most often referenced research mostly focuses on industrial digitalization, IoT-enabled monitoring, AI-supported optimization, and sustainability. The logistic distribution had the strongest visual match with the observed pattern, indicating that a small number of articles have had a significant impact on the field's conceptual evolution.

Additionally, Figure 1 aids in locating publications whose citation patterns deviate from the core distribution. To ascertain if the effect of these studies represented conceptual originality, multidisciplinary relevance, or the early presentation of topics that subsequently became fundamental to Industry 5.0, a qualitative analysis of these studies was conducted.

The comparison of theoretical distributions helped identify research gaps and trends. While technology integration, process efficiency, and sustainability are well-established, worker involvement, digital competences, organizational flexibility, ethical governance, and human decision-making are still in their infancy. In terms of methodology, citation analysis was not used as a stand-alone indicator of scientific quality but rather as an additional mapping tool.

This method identified important research, theme concentrations, and unexplored regions by tying bibliometric trends with qualitative interpretation.

4.2 Bibliometric Analysis

The VOSviewer analysis mapped the conceptual relationships among the key terms identified in the selected articles. "Machine learning," "real-time monitoring," "human-machine collaboration," "sustainability," "digital infrastructure," and "ethical technology" were among the terms that often appeared together. These words represented the main topics of Industry 5.0 study and held significant places in the conceptual network.

Particularly noticeable were three topic areas:

- Predictive analytics, adaptive decision support, maintenance, and process optimization are all related to machine learning.
- Real-time monitoring, connected systems, industrial safety, operational effectiveness, and dynamic resource management.
- Human-machine cooperation, including employee involvement, human-centered automation, organizational flexibility, and the maintenance of human agency.

Figure 2 presents the conceptual map generated from the co-occurrence analysis and illustrates the relationships among the principal theoretical categories and emerging themes.

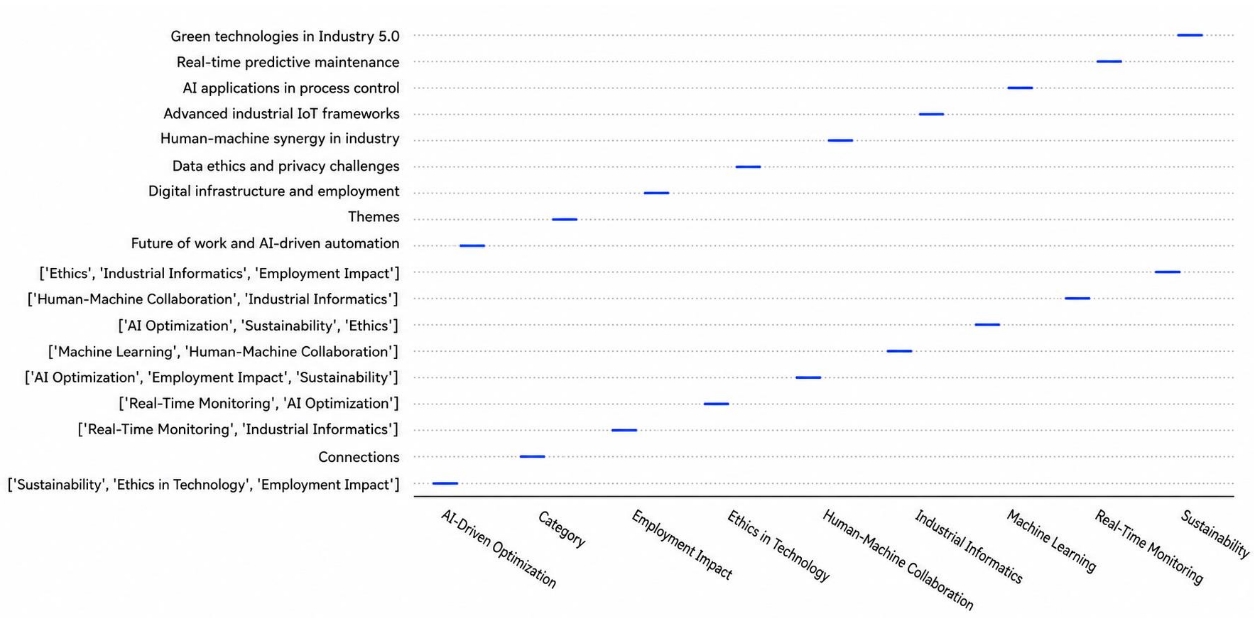

Figure 2. Conceptual Map of Theoretical Interactions and Emerging Themes in Industry 5.0

Source: Author

The conceptual network illustrates Industry 5.0's interdisciplinary nature, as shown in Figure 2.

Digital infrastructure, machine learning, sustainability, technology ethics, real-time monitoring, and employment-related consequences were among the most linked nodes.

Their closeness suggests that industrial optimization is becoming more widely recognized as a sociotechnical process including organizational, technological, environmental, and human components.

Three pertinent relationships emerged from the mapping. First, human-machine cooperation and machine learning emerged as interrelated pillars, suggesting that technology intelligence is becoming more closely linked to human involvement rather than labor replacement. Second, there was a major thematic confluence between ethics and sustainability that included environmental effect, privacy, transparency, and responsible data usage. Third, the connection between workforce development, employment, and digital infrastructure emphasized the significance of professional adaptability, organizational learning, and competences.

The study revealed twenty-eight emergent themes, sixteen theoretical connections, and eight conceptual categories. By comparing these results with oral, documentary, and visual data, bibliometric mapping was able to serve as a foundation for qualitative interpretation rather than as a stand-alone quantitative outcome.

4.3 Data Triangulation

The systematic literature review, bibliometric analysis, semi-structured expert interviews, and documentary and visual data were all incorporated into the triangulation process.

Expert interviews offered professional interpretations, bibliometric analysis revealed theme connections, documentary and visual materials contextualized technology implementations, and the literature study provided the conceptual groundwork. A cross-source comparison showed agreement on workforce development, sustainability, responsible automation, and human-machine cooperation. Additionally, differences were noted. While experts concentrated more on implementation challenges, digital competences, ethical obligations, and organizational preparedness, the literature highlighted predictive technology and efficiency. As a result, triangulation promoted a more comprehensive understanding of Industry 5.0 and made a distinction between topics that were prevalent in the literature and those that were thought to be most pertinent in real-world applications.

4.4 Expert Interviews

Professionals with expertise in Industry 5.0, digital transformation, industrial innovation, AI-IoT deployment, or mobile apps participated in fifteen semi-structured interviews. A minimum of five years of relevant experience, direct participation in AI-IoT projects, and professional backgrounds in academia, industry, technology, consulting, or governance were the criteria used to purposively choose participants. AI and IoT may enhance process visibility, predictive capability, operational responsiveness, and worker-automated system cooperation, according to the participants. They did stress, however, that worker preparation, data quality, organizational preparedness, and transparent ethical governance are all necessary for success.

Three recurring themes were maintaining human supervision in automated decision-making, enhancing workforce development and digital competences, and coordinating technology adoption with corporate goals, sustainability, and safety.

Table 1. presents a representative sample of the professional profiles included in the interviews.

Expert ID	Position	Expertise	Sector
E1	AI Systems Engineer	Predictive Maintenance, IoT	Manufacturing
E2	Automation Consultant	Human-Machine Collaboration	Private Consulting
E3	University Professor	Smart Factories, Industry 5.0	Academia
E4	Innovation Director	AI Governance, Digital Twins	Industrial Consortium
E5	Software Architect	Mobile Apps, Edge Computing	Technology Firm

Source: Author.

Table 1 shows five representative profiles from the total group of 15 participants. The remaining profiles were not reproduced individually to preserve concision and participant confidentiality. It was possible to compare technical, organizational, academic, and governance viewpoints on Industry 5.0 because of the participants' diversity. The interviews supported themes found in the literature, such as workforce development, human-machine cooperation, predictive maintenance, and real-time monitoring. They also uncovered issues that were not as evident in the bibliometric study, such organizational change resistance, disparities in digital proficiency, challenges in deciphering algorithmic suggestions, and ambiguity around accountability for automated judgments.

4.5 Documentary Analysis

To find implementation trends, operational obstacles, and new priorities, industrial reports and documentary materials were analyzed. The data demonstrated the growing usage of IoT and AI-enabled systems for workplace safety, quality control, process monitoring, predictive maintenance, and resource management.

Disjointed data infrastructures, poor interoperability, inadequate worker training, cybersecurity threats, and ambiguous governance practices were among the ongoing difficulties. Sustainability was often emphasized as a top concern, but its implementation in quantifiable operating procedures was inconsistent. The results show that while some firms continue to deploy standalone apps without a thorough human-centered approach, others have incorporated AI and IoT into coordinated systems.

4.6 Visual Data Analysis

To investigate their portrayal in industrial settings, visual resources pertaining to AI, IoT, mobile apps, real-time monitoring, and automated systems were examined. Connected equipment, monitoring interfaces, cooperative robotics, predictive dashboards, and human supervision were recurring components.

The visual evidence shows that Industry 5.0 reconfigures human engagement rather than eliminating it. In electronically mediated workplaces, employees are more often seen as coordinators, managers, translators, and decision-makers.

Figure 3 summarizes the integration of expert interviews, documentary analysis, visual evidence, and the broader literature-based findings.

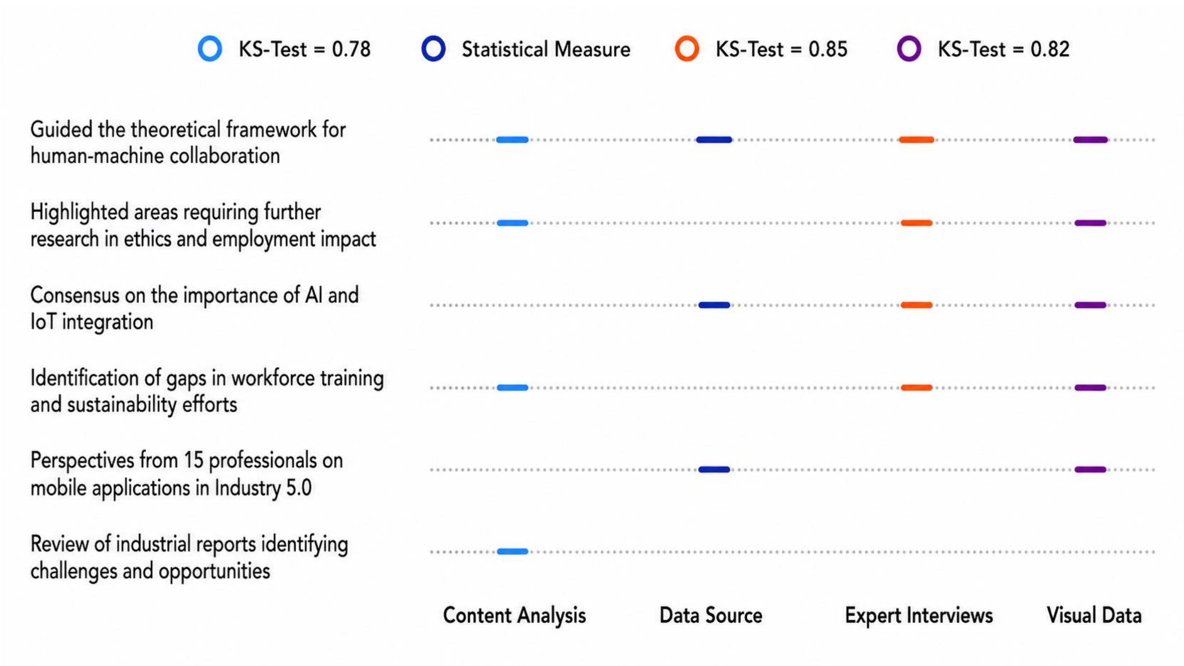

Figure 3. Data Triangulation and Analytical Integration in Industry 5.0
Source: Author.

Figure 3 presents the contribution of each source to the development of the qualitative framework. Documentary analysis revealed industry goals and obstacles, while expert interviews highlighted implementation and organizational preparedness. The literature study and bibliometric mapping supplied the intellectual foundation for interpretation, while visual data contextualized worker-technology interaction. Human-machine cooperation, ethical governance, human supervision, digital competences, workforce development, sustainability, safety, and operational efficiency were identified as key components of industrial optimization via convergence across various sources.

The triangulated results show that, when backed by organizational structures that uphold human judgment and guarantee proper governance, AI- and IoT-enabled mobile apps may enhance efficiency, safety, resilience, and sustainability. Therefore, rather than only being a technology update, Industry 5.0 should be seen as a sociotechnical change.

5. Discussion

This study provides a qualitative analysis of how AI- and IoT-enabled mobile applications are transforming industrial processes within Industry 5.0. The results show that these technologies redefine the interaction between technical systems and human decision-making while also contributing to process optimization via operational responsiveness, real-time monitoring, and predictive capacity. Industry 5.0 places a higher priority on human-machine cooperation, ethical governance, organizational resilience, and sustainability than automation-centered approaches.

The systematic literature review and bibliometric analysis identified eight conceptual categories, sixteen theoretical connections, and twenty-eight emerging themes. Digital infrastructure, human-machine cooperation, machine learning, ethical technology, sustainability, and real-time monitoring all held key roles. Because of their interdependence, industrial optimization should be viewed as a sociotechnical process where workforce competencies, organizational structures, technological capabilities, and human values all affect performance.

Predictive maintenance, process management, and adaptive decision-making were especially pertinent to machine learning and real-time monitoring. But technological performance by itself does not ensure successful deployment. Expert opinions focused on human supervision, worker preparation, organizational preparedness, and data quality. According to these results, Industry 5.0 necessitates the coordinated development of human and technological skills, especially via focused training and improved digital competences (Butt et al., 2025).

The literature, interviews, documentary records, and visual evidence all consistently showed human-machine partnership. In digitally mediated contexts, AI and IoT reposition workers as supervisors, translators, coordinators, and decision-makers rather than replacing them. This result is consistent with Industry 5.0's human-centered approach, which aims to increase human potential while maintaining agency and accountability. The findings also showed that sustainability and ethical governance are closely related. Environmental and organizational goals were often linked to transparency, privacy, accountability, data usage, and employment effect. Therefore, governance systems that can handle the social and ecological effects of technology adoption are necessary for responsible industrial change. It is important to see ethical AI as an operational need rather than an afterthought.

By combining the systematic review, bibliometric mapping, expert interviews, documentary sources, and visual evidence, triangulation enhanced the study's interpretative depth. Human-machine cooperation, responsible automation, workforce development, and sustainability were all areas of convergence. The sources' emphasis varied, though. While experts emphasized organizational hurdles, professional abilities, governance duties, and implementation hazards, the scholarly literature concentrated more on predictive technology, efficiency, and process optimization. This disparity highlights the need to integrate experience-based and literature-based evidence in qualitative research.

By making it easier to identify conceptual links, theme concentrations, and recurrent analytical patterns, VOSviewer and NVivo aided in the structuring and understanding of the data (Sanni et al., 2024). While NVivo facilitated the methodical comparison of themes across diverse qualitative sources, VOSviewer made it possible to map relationships within the literature.

Incorporating bibliometric mapping, theme analysis, expert viewpoints, documentary and visual material into a more comprehensive qualitative approach is the methodological contribution. The study employed bibliometric indicators to interpret conceptual patterns, research gaps, and sociotechnical implications rather than treating them as independent measures. For analyzing technological change in diverse industrial and digitally mediated environments, this method provides a transferable analytical framework. However, it is important to evaluate the results within the parameters of the research. The selection of databases, a specified publication period, and certain topic criteria were all restrictions on the literature review. The expert interviews did not aim to represent all industrial sectors or geographical situations; rather, they represented carefully chosen professional viewpoints. The level of depth and comparability in documentary and visual sources also differed. Without further contextual analysis, these constraints limit the framework's applicability.

In general, when used in accordance with human-centered concepts, mobile apps enabled by AI and IoT may support more effective, robust, safe, and sustainable industrial systems. Therefore, combining technology innovation with ethical governance, organizational adaptability, worker development, and environmental responsibility is essential to Industry 5.0's success. By seeing industrial change as a multifaceted process encompassing technology, institutions, and human action, the suggested framework advances qualitative research.

6. Methodological Reflection

The methodological design of this study was grounded in a qualitative sociotechnical perspective, according to which Industry 5.0 cannot be adequately understood through technological performance indicators alone. Instead, industrial transformation was interpreted as a process shaped by the interaction among technological systems, human agency, organizational conditions, ethical considerations, and sustainability objectives. This epistemological position guided the selection and interpretation of the different sources of evidence used throughout the study.

A central methodological decision was to integrate a systematic literature review, bibliometric analysis, semi-structured expert interviews, documentary analysis, visual evidence, and qualitative thematic and narrative analysis. This combination was selected because no single source could adequately capture the technological, organizational, ethical, and human dimensions of Industry 5.0. Bibliometric analysis was therefore used as a complementary mapping technique rather than as an independent quantitative outcome. Its purpose was to identify conceptual relationships, thematic concentrations, and emerging research areas that could subsequently be interpreted within the broader qualitative framework.

The methodological process also involved several limitations and practical constraints. The systematic literature review was bounded by the selected databases, publication period, search criteria, and inclusion procedures. The purposive sample of fifteen experts was intended to provide analytically relevant professional perspectives rather than statistical representativeness. Documentary and visual materials also varied in scope, level of detail, and contextual comparability. These differences required particular attention during triangulation and prevented the assumption that convergence among sources necessarily represented complete agreement.

Researcher reflexivity was an important component of the analytical process. The identification of codes, categories, relationships, and emerging themes necessarily involved interpretive judgment. To strengthen analytical rigor, two researchers independently applied thematic and narrative codes to a representative sample, compared their interpretations, discussed disagreements, and iteratively refined the codebook. Cohen's Kappa was used as one indicator of intercoder consistency, while triangulation and collaborative interpretation were used to preserve the contextual and interpretive character of the qualitative analysis.

One transferable methodological lesson is that bibliometric tools can contribute meaningfully to qualitative research when their outputs are interpreted contextually rather than treated as self-explanatory quantitative indicators. Similarly, triangulation should not be understood solely as a procedure for confirming agreement among sources, but also as a means of identifying differences, tensions, and complementary perspectives. The methodological approach developed in this study may therefore be adapted to other qualitative investigations of sociotechnical transformation, provided that researchers adjust the sources, coding procedures, reflexive practices, and validation strategies to the characteristics of each research context.

7. Conclusions

Within the human-centered paradigm of Industry 5.0, this research created a qualitative framework for comprehending how mobile apps enabled by AI and IoT contribute to industrial process improvement. The study found eight conceptual categories, sixteen theoretical linkages, and twenty-eight emergent themes by combining a systematic literature review, bibliometric analysis, semi-structured expert interviews, and documentary and visual evidence.

The results show that when AI and IoT are implemented in accordance with human competences, organizational preparedness, responsible governance, and meaningful human supervision, they may enable more effective, robust, safe, and sustainable industrial processes. A key need of this change was human-machine cooperation, with technology enhancing rather than supplanting human capacities. By combining bibliometric mapping, theme analysis, and triangulated qualitative data into a transferable framework for analyzing sociotechnical transition, the research makes a methodological contribution. Additionally, it emphasizes the necessity of digital competencies, ethical governance, workforce training, and organizational strategies focused on sustainability. The purposeful sample, publication time, databases used, and the diversity of visual and documentary sources all have an impact on the results.

Future studies should use the framework in a variety of industries and settings and look at managers' and employees' experiences with AI-IoT adoption throughout time. Overall, by seeing industrial change as a linked technical, organizational, ethical, and human process, the study enhances qualitative research on Industry 5.0.

Ethical Approval: Institutional ethical approval was not required for this study under the applicable institutional regulations because the research involved non-clinical interviews with adult professionals and did not involve medical interventions or the collection of clinical data. All participants provided informed consent, and confidentiality, anonymity, and voluntary participation were maintained throughout the research process

Informed Consent: Informed consent was obtained from all participants, ensuring confidentiality, anonymity, and voluntary participation.

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