Research Article

International Journal of Blockchain Applications and Financial Technology

Applications of Artificial Intelligence and Iot Technologies in Smart Manufacturing- Case Study of Emirates Global Aluminium (EGA)

Shankar Subramanian Iyer[1]*, Brinitha Raji[2], Rajesh Arora[3] & Raman Subramanian[4]

[1]*Business; Senior Faculty,Westford University College, Sharjah, UAE*
[2]*Global Business Studies, Senior Faculty, DKP, Dubai*
[3]*Business; Senior FacultyWestford University College, Al Khan, Sharjah*
[4]*Associate Dean, Westford University College, Al Tawuun, Sharjah, UAE*

***Corresponding author:** Shankar Subramanian Iyer, Business; Westford University College, Sharjah, UAE.

Submitted: 25 September 2025 **Accepted:** 03 October 2025 **Published:** 10 October 2025

https://doi.org/10.63620/MKIJBAFT.2025.1001

Citation: *Iyer, S. S., Raji, B., Arora, R., & Subramanian, R. (2025). Applications of Artificial Intelligence and Iot Technologies in Smart Manufacturing-Case Study of Emirates Global Aluminium (EGA). Int J of Blockchain App Fin Tech, 1(1), 01-10.*

Abstract

The convergence of Artificial Intelligence (AI) and Internet of Things (IoT) technologies is reshaping the landscape of global manufacturing by enabling real-time data-driven decision-making, predictive analytics, and autonomous operations. This research investigates the practical applications, challenges, and strategic implications of integrating AI and IoT in smart manufacturing through an in-depth case study of Emirates Global Aluminium (EGA), one of the world's leading aluminium producers based in the United Arab Emirates. By conducting semi-structured interviews with 15 domain experts, including plant managers, IT engineers, automation specialists, and AI consultants, the study captures rich qualitative insights into the technological transformation taking place within EGA's production ecosystem. The findings reveal that AI and IoT have significantly enhanced operational efficiency at EGA through predictive maintenance, energy optimization, process automation, and real-time quality control. Experts emphasized the critical role of machine learning algorithms in forecasting equipment failures and the use of IoT-enabled sensors in tracking environmental and performance metrics. Furthermore, the adoption of AIoT technologies has improved data interoperability across departments, contributing to more agile and responsive manufacturing workflows. This study contributes to the growing body of Industry 4.0 literature by offering a grounded case of AI-IoT synergy within a regional industrial leader, thereby bridging the gap between conceptual frameworks and operational realities. It also proposes a customized smart manufacturing framework aligned with EGA's strategic goals and technological maturity. The implications of the study are both practical and theoretical. Practically, it provides a roadmap for other industrial players in the Middle East seeking to integrate AIoT solutions for enhanced productivity and sustainability. Theoretically, it enriches our understanding of digital transformation in resource-intensive sectors, offering empirical evidence for models like the Technology-Organization-Environment (TOE) framework and the Dynamic Capabilities Theory. The study also underscores the need for addressing challenges such as cybersecurity vulnerabilities, data governance, talent gaps, and integration costs, which must be strategically managed to ensure long-term competitiveness. This research demonstrates how a forward-thinking industrial enterprise like EGA leverages AI and IoT to remain at the forefront of smart manufacturing, offering valuable lessons for policymakers, practitioners, and academic scholars engaged in digital industrial transformation.

Keywords: Artificial Intelligence (AI), Internet of Things (IoT), Smart Manufacturing, Emirates Global Aluminium (EGA), Industry 4.0, AIoT, Predictive Maintenance, Operational Efficiency, Digital Transformation, Middle East Industrial Innovation.

Introduction

The evolution of manufacturing in the digital age has been significantly accelerated by the convergence of Artificial Intelligence (AI) and the Internet of Things (IoT), technologies that form the backbone of Industry 4.0. This digital transformation is redefining traditional manufacturing processes by embedding intelligence and connectivity into machinery, production lines, and enterprise systems. In this context, smart manufacturing refers to the integration of advanced digital technologies that enable predictive decision-making, real-time monitoring, and autonomous process control. AI contributes by enabling machines to learn from data and improve performance autonomously, while IoT connects physical assets and systems, facilitating seamless data exchange and operational transparency.

The integration of these two technologies—collectively referred to as AIoT—offers unprecedented opportunities for enhancing productivity, quality, flexibility, and sustainability in manufacturing systems. The dawn of Industry 4.0 has heralded a technological revolution in the manufacturing sector, characterized by the convergence of digital technologies that redefine traditional industrial operations. Among the most transformative technologies are Artificial Intelligence (AI) and the Internet of Things (IoT), which collectively form the backbone of Smart Manufacturing. These technologies are not only automating processes but are also making manufacturing systems more intelligent, agile, and adaptive. AI contributes to enhanced decision-making through machine learning, natural language processing, and predictive analytics, while IoT enables seamless interconnectivity between machines, systems, and humans, facilitating real-time data acquisition, monitoring, and control [1].

This study focuses on the practical application and strategic significance of AI and IoT (AIoT) in the smart manufacturing transformation of Emirates Global Aluminium (EGA), one of the UAE's flagship industrial entities and a global leader in the aluminium production sector. The research is grounded in a qualitative methodology, drawing on insights from 15 expert interviews with professionals engaged in operations, IT, digital strategy, and automation at EGA. The study aims to explore how AIoT technologies are deployed across EGA's manufacturing processes, assess the organizational readiness for digital transformation, and identify both the benefits and the systemic challenges encountered during implementation. The research not only provides a contextualized view of technological advancement in a key Gulf-based industrial player but also contributes to the broader academic discourse on smart manufacturing and digital capability development in heavy industries (Artificial Intelligence of Things (AIOT) for Productivity and Organizational Transition, 2024).

Background

In recent years, global manufacturing industries have faced increasing pressure to modernize operations in response to growing competition, market volatility, energy efficiency requirements, and sustainability goals. The Fourth Industrial Revolution, or Industry 4.0, has emerged as a strategic paradigm to address these pressures by embedding intelligence and interconnectivity into manufacturing ecosystems. Among the most impactful technologies underpinning this shift are Artificial Intelligence and the Internet of Things. AI enables complex pattern recognition, decision-making automation, and predictive analytics, while IoT technologies provide real-time monitoring, equipment interlinking, and data-driven process optimization. Together, these technologies empower manufacturers to move from reactive to proactive and even autonomous operational models [2].

The UAE, under its national innovation and industrial strategies (e.g., UAE Industry 4.0, Operation 300bn), is investing heavily in smart technology to enhance local industrial competitiveness. Emirates Global Aluminium (EGA), the largest industrial company in the UAE outside the oil and gas sector, stands at the forefront of this transformation. With complex aluminium smelting and casting operations that demand precision, safety, and efficiency, EGA has adopted AI and IoT technologies to optimize production scheduling, reduce downtime through predictive maintenance, improve energy efficiency, and ensure consistent product quality. The organization's efforts reflect a broader commitment to digital transformation as a strategic pillar for maintaining global competitiveness [3].

This study is particularly timely as it explores not only the technological applications within EGA's smart manufacturing initiatives but also addresses organizational, cultural, and infrastructural enablers and barriers to AIoT implementation. By examining the EGA case, the research contributes a valuable industry-specific understanding of how AI and IoT technologies are reshaping manufacturing processes in resource-intensive environments. It also provides practical and theoretical implications for manufacturing leaders, digital transformation strategists, and policymakers aiming to foster technology adoption in the Middle East and other emerging industrial regions [4].

Research Scope

This research investigates the strategic and operational impact of Artificial Intelligence (AI) and Internet of Things (IoT) technologies on smart manufacturing practices within Emirates Global Aluminium (EGA), a leading industrial enterprise in the United Arab Emirates. The study focuses on understanding how the integration of AI and IoT—collectively referred to as AIoT—enhances manufacturing performance across various operational domains, such as efficiency, quality control, energy usage, and predictive maintenance. The research is bounded within EGA's operational facilities and incorporates qualitative insights from 15 domain experts, including managers, engineers, and digital transformation specialists. The scope also includes an examination of the organization's digital transformation readiness, supporting infrastructure, and data governance practices that influence the adoption and performance of AIoT systems. By adopting a multi-theoretical framework and case study approach, this research aims to provide actionable insights and theoretical contributions relevant to Industry 4.0 transitions in resource-intensive sectors.

Research Questions

- How do Artificial Intelligence capabilities influence smart manufacturing performance outcomes such as predictive maintenance, energy efficiency, and product quality at EGA?
- In what ways does IoT integration and infrastructure affect EGA's ability to achieve real-time monitoring, operational efficiency, and production agility?
- What organizational factors determine EGA's readiness for digital transformation, and how do they support or hinder the successful adoption of AIoT technologies?
- How do data management systems and cybersecurity protocols influence the effectiveness and trustworthiness of AIoT applications in EGA's manufacturing processes?

Research Objectives

- To evaluate how Artificial Intelligence capabilities such as machine learning, computer vision, and decision support systems contribute to enhancing smart manufacturing performance at EGA.
- To examine the role of IoT integration and infrastructure—including sensors, edge devices, and industrial platforms—in influencing operational outcomes and production flexibility at EGA.
- To assess the level of digital transformation readiness at EGA, including leadership commitment, skills, and innovation culture, and its effect on AIoT-driven manufacturing efficiency.
- To analyse how data management and cybersecurity practices impact the reliability, interoperability, and scalability of AI and IoT technologies in EGA's smart manufacturing ecosystem.

Literature Review

The global manufacturing sector is undergoing rapid transformation driven by the convergence of emerging technologies under the industry 4.0 paradigm. Among these, Artificial Intelligence (AI) and the Internet of Things (IoT) stand out as key enablers of Smart Manufacturing, where systems are increasingly intelligent, self-optimizing, and interconnected. Numerous scholars have emphasized AI's potential in predictive analytics, process optimization, and autonomous decision-making in manufacturing [5, 6]. AI technologies such as machine learning, natural language processing (NLP), computer vision systems, and decision support systems have been widely adopted to enhance forecasting, quality assurance, and real-time diagnostics [7]. These technologies support adaptive manufacturing, where decisions are not only automated but also contextual and data driven.

In parallel, IoT technologies provide the digital backbone for real-time data collection, transmission, and communication among machines, systems, and sensors [8]. IoT integration involves sensor deployment, data acquisition systems, edge computing devices, and industrial IoT platforms, which together enable a seamless flow of operational data across manufacturing networks. Scholars such as Kilari and Yu have highlighted how IoT infrastructure enables real-time monitoring, asset tracking, and performance management, laying the foundation for AI to process and interpret operational data intelligently. The interdependence of AI and IoT—referred to as AIoT—has emerged as a focal point for enhancing manufacturing agility, energy efficiency, and process control [9, 10].

Smart Manufacturing Performance is increasingly being defined through multidimensional indicators such as operational efficiency, production flexibility, product quality, energy efficiency, and predictive maintenance capabilities [11]. These outcomes are critical in high-capital industries like aluminium manufacturing, where even minor inefficiencies can lead to substantial cost implications. Empirical studies by Rahmayanti and George have linked AIoT implementations to measurable improvements in performance metrics, particularly in areas of downtime reduction, scrap minimization, and process visibility [12, 13].

Another critical construct explored in the literature is Digital Transformation Readiness. This includes a firm's preparedness in terms of digital skills and training, leadership commitment, technology infrastructure, and innovation culture [14, 15]. Organizational readiness is considered a key enabler for adopting complex technologies and aligning them with long-term strategic goals. Without proper change management processes and digital governance, technology adoption efforts often remain fragmented or fail to yield sustainable results.

Furthermore, Data Management and Cybersecurity have emerged as non-negotiable pillars of any digital transformation initiative. Studies by Sadeghi & Wachsmann and Sun et al. indicate that the success of AI and IoT deployments heavily depends on the organization's ability to manage data collection accuracy, real-time analytics, data governance policies, and cybersecurity protocols. In industrial settings like EGA's, the protection of proprietary data and infrastructure from cyber threats is essential for maintaining operational continuity and stakeholder trust [16, 17].

To theoretically anchor these variables, the study integrates multiple frameworks. The Technology-Organization-Environment (TOE) framework provides a holistic view of how technological capabilities, organizational readiness, and environmental conditions influence innovation adoption [18]. The Resource-Based View (RBV) emphasizes the importance of leveraging internal technological capabilities—such as AI and IoT—as strategic assets [19]. The Dynamic Capabilities Theory (DCT) highlights an organization's ability to integrate, build, and reconfigure internal competencies to address rapidly changing environments [20]. Additionally, Socio-Technical Systems (STS) theory underscores the interaction between human and technical elements in digital systems, while Diffusion of Innovation (DOI) theory explains the patterns and stages of technological adoption within firms [21].

Literature Gaps

While prior research has established the strategic potential of AI and IoT in manufacturing, limited empirical studies exist that focus on integrated AIoT implementation in resource-intensive sectors like aluminium production, particularly in the Middle Eastern context. Most existing models treat AI and IoT separately, overlooking the synergistic impact of AIoT systems in creating responsive and intelligent manufacturing ecosystems. Additionally, few studies incorporate organizational enablers such as digital readiness and data governance in the same conceptual model, despite growing consensus on their critical role in successful transformation initiatives [5, 22].

Moreover, literature has largely emphasized case studies from Western or Asian markets, while practical evidence from Gulf-based industrial enterprises remains scarce, thereby limiting contextual relevance for organizations like Emirates Global Aluminium (EGA). Another important gap is the lack of multi-theoretical integration in most existing studies. While TOE and RBV are frequently cited, there is a need to incorporate complementary lenses such as Dynamic Capabilities and Socio-Technical Systems Theory to fully understand the socio-technical complexity and strategic agility required for successful smart manufacturing transformation.

This research addresses these gaps by proposing an integrated conceptual model involving four core variables—Artificial Intelligence Capabilities, IoT Integration and Infrastructure, Digital Transformation Readiness, and Data Management and Cybersecurity—and assessing their influence on Smart Manufacturing Performance at EGA. The study uses multiple theoretical frameworks to ensure a comprehensive analysis of technological, organizational, and environmental determinants. The 15 expert interviews enrich the empirical understanding of AIoT implementation, offering practical insights that bridge the gap between theoretical constructs and industry application.

Theoretical Framework

To examine the multifaceted influence of AI and IoT technologies on smart manufacturing performance at Emirates Global Aluminium (EGA), this research integrates five complementary theoretical perspectives: the Technology-Organization-Environment (TOE) Framework, Resource-Based View (RBV), Dynamic Capabilities Theory (DCT), Socio-Technical Systems (STS) Theory, and the Diffusion of Innovation (DOI) Theory. This integrative theoretical approach provides a comprehensive lens through which both the technological and organizational complexities of digital transformation in manufacturing can be understood.

The Technology-Organization-Environment (TOE) framework, proposed by Tornatzky and Fleischer, offers a foundational structure for assessing how technology adoption is influenced by three key contexts: the technological capabilities available, the internal organizational context, and the external environment. In the present study, Artificial Intelligence Capabilities (e.g., machine learning, NLP, computer vision) and IoT Integration and Infrastructure (e.g., sensor networks, industrial platforms) fall under the technological dimension [18]. The organizational dimension is captured through Digital Transformation Readiness, including leadership commitment, training, and innovation culture, while Data Management and Cybersecurity practices address both internal and external environmental preparedness. The TOE framework is particularly useful in understanding the multidimensional interactions required to achieve optimal smart manufacturing performance [23].

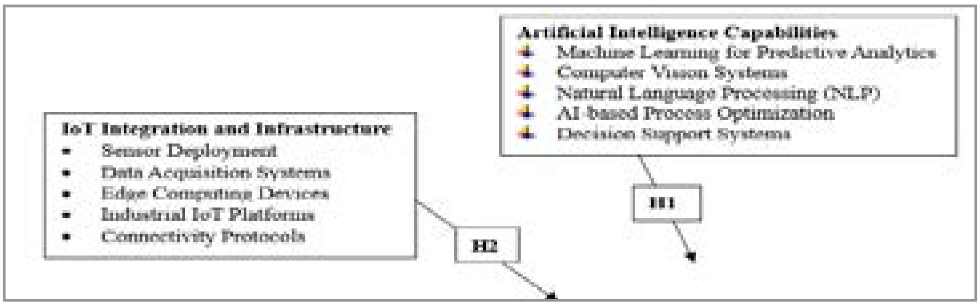
The Resource-Based View (RBV) complements the TOE framework by emphasizing that internal technological and human resources—when valuable, rare, inimitable, and non-substitutable—can lead to sustained competitive advantage [19]. At EGA, the presence of AI capabilities and IoT infrastructure is seen as strategic assets that enhance operational performance and innovation. These resources, however, must be well-aligned with the firm's strategic intent and effectively integrated across departments. The RBV supports the idea that smart manufacturing performance is a direct result of how organizations leverage and mobilize their unique internal capabilities, particularly those tied to digital technologies and data analytics [24].

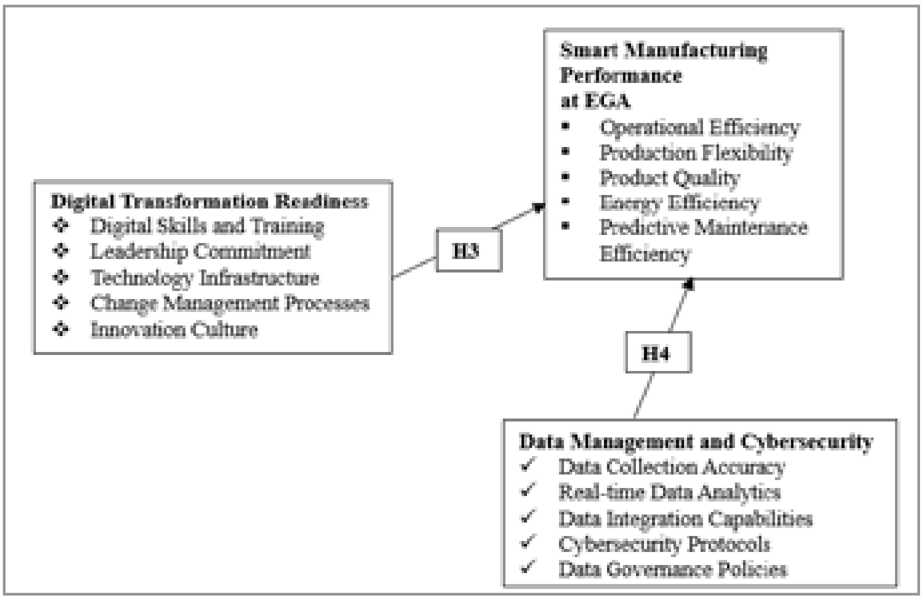
The Dynamic Capabilities Theory (DCT) extends the RBV by focusing on the organization's ability to sense, seize, and transform in rapidly changing environments [20]. In the context of EGA, digital transformation readiness reflects these dynamic capabilities—especially through the firm's ability to reskill its workforce, adapt to technological innovations, and embed new processes into existing operations. These dynamic capabilities are essential for the effective deployment and evolution of AIoT technologies in manufacturing contexts characterized by scale, complexity, and sustainability requirements. To address the interplay between technological systems and human/organizational factors, the study also draws on Socio-Technical Systems (STS) Theory. This perspective posits that technological change in complex systems like manufacturing cannot succeed without simultaneous changes in organizational structures, roles, and cultures. The successful implementation of AI and IoT at EGA requires not just technological tools, but alignment with worker competencies, cross-functional collaboration, and change management. STS theory reinforces the importance of Digital Transformation Readiness and Data Governance as socio-organizational factors critical to achieving effective AIoT integration [25].

Lastly, Diffusion of Innovation (DOI) Theory offers a behavioral perspective by explaining how new technologies are adopted and spread within organizations [21]. The theory's five innovation characteristics—relative advantage, compatibility, complexity, trialability, and observability—are relevant for understanding how AIoT adoption progresses at EGA. For example, the perceived complexity of integrating AI algorithms with IoT sensors could delay adoption unless offset by clear performance benefits (relative advantage) and strong leadership support. DOI theory helps to explain the patterns of resistance, acceleration, and acceptance seen in the qualitative findings from EGA's workforce [26].

By integrating these five theoretical perspectives, the conceptual model is robustly grounded and capable of capturing the technological, strategic, and behavioral dimensions of AIoT adoption. The hypotheses (H1–H4) are thus formed to empirically test how Artificial Intelligence Capabilities, IoT Integration, Digital Transformation Readiness, and Data Management and Cybersecurity influence Smart Manufacturing Performance—measured through key operational indicators relevant to EGA's business and the broader goals of sustainable industrial competitiveness.

Conceptual using the integrated Technology-Organization-Environment (TOE) Framework, Resource-Based View (RBV), Dynamic Capabilities Theory (DCT), Socio-Technical Systems Theory (STS), and Diffusion of Innovation Theory (DOI)





Hypotheses

H1: The Artificial Intelligence Capabilities have a significant influence on Smart Manufacturing Performance at EGA

H2: Smart Manufacturing Performance at EGA is significantly influenced by IoT Integration and Infrastructure

H3: The Digital Transformation Readiness have a significant influence on Smart Manufacturing Performance at EGA

H4: Smart Manufacturing Performance at EGA is significantly influenced by Data Management and Cybersecurity

Methodology

This research adopts the Research Onion framework developed by Saunders et al. to provide a structured, layered approach to methodological design [27]. The framework facilitates a clear alignment between the philosophical foundation, research strategy, time horizon, data collection techniques, and the overall purpose of the study. The central objective of this research is to explore how AI and IoT technologies influence smart manufacturing performance at Emirates Global Aluminium (EGA), and how organizational readiness and data practices mediate this influence. As such, the methodology is designed to capture deep, context-specific, and expert-driven insights.

At the outermost layer of the onion, the study is grounded in an interpretivist research philosophy, which recognizes that the reality of AIoT integration in manufacturing is socially constructed and contextually influenced. Interpretivism is particularly suitable for this study because it seeks to understand subjective expert experiences and perspectives on digital transformation within EGA. Unlike positivist approaches that aim for generalizability, interpretivism allows for nuanced exploration and meaning making through dialogue with stakeholders, thus providing richer qualitative insights into technological adoption and operational challenges [28].

The research employs an abductive research approach, which combines elements of both inductive and deductive reasoning. This approach enables the researcher to start with a conceptual model grounded in existing theory (TOE, RBV, DCT, STS, DOI), while remaining open to revising or expanding this model based on the empirical findings from interviews. Abduction is appropriate in under-researched domains such as AIoT applications in UAE-based heavy industries, where both theory refinement and new theme discovery are essential.

Aligned with the interpretivist philosophy and abductive approach, the study uses a case study strategy focusing exclusively on Emirates Global Aluminium (EGA). A single embedded case study design allows for an in-depth examination of how AI and IoT technologies are integrated into manufacturing processes and how organizational factors such as digital readiness, data governance, and cybersecurity influence outcomes.

The case study method is especially effective for answering "how" and "why" questions within a real-life organizational context, making it an ideal choice for exploring complex, interdependent variables [29]. The methodological choice is a qualitative mono-method, relying on semi-structured interviews as the primary data collection tool. This qualitative method allows for open-ended responses and deeper probing into areas such as technology deployment, workforce transformation, leadership challenges, and data management strategies. A total of 15 domain experts from EGA were selected using purposive sampling to ensure relevance and expertise. Participants included AI engineers, digital strategy heads, plant operations managers, and cybersecurity officers. Each interview lasted between 45 to 60 minutes and was conducted either in person or via secure video conferencing platforms, with informed consent obtained prior to recording and transcription.

The research adopts a cross-sectional time horizon, capturing the state of AIoT implementation at EGA during a specific timeframe. While digital transformation is an evolving process, the study seeks to provide a snapshot of current practices, challenges, and strategic implications of AI and IoT integration within the manufacturing ecosystem. This time-bound design supports the research objective of evaluating current performance drivers and readiness indicators rather than tracking long-term change.

For data analysis, the study uses thematic analysis following Braun and Clarke's six-phase framework: familiarization with data, coding, theme generation, theme review, theme definition, and final reporting [30]. Thematic analysis enables both deductive coding (aligned with the conceptual model and hypotheses) and inductive theme emergence, allowing for a flexible yet structured interpretation of expert insights. Data were analysed manually and cross-validated for consistency, with themes mapped directly to the key variables of AI capabilities, IoT infrastructure, digital transformation readiness, data management, and smart manufacturing outcomes [31].

Finally, ethical considerations were rigorously observed. Participants were informed of their rights, the voluntary nature of participation, and data confidentiality. Anonymization protocols were applied to protect identities, and all data were stored securely for academic use only. Ethical approval was obtained in advance to ensure compliance with research integrity standards.

The methodology adopted in this study is robust, context-sensitive, and well-suited to address the research objectives. By using the Research Onion framework, this study provides a clear rationale for each methodological decision and ensures consistency between theoretical grounding and empirical inquiry. The result is a rich, qualitative exploration of AIoT adoption in a strategically important manufacturing organization in the UAE, with valuable implications for both scholars and industry practitioners [32].

Interviewee Summary Table – EGA Smart Manufacturing Study

Interviewee No.	Experience (Years)	Designation	Department/Sector	Key Insight Area
1	18	AI Engineer	AI & ML Division	Machine learning models improved predictive maintenance scheduling
2	22	Plant Operations Manager	Smelting Operations	AI systems reduced production waste by 12% in smelting operations
3	15	Head of IoT Systems	IoT Systems	IoT sensors enabled real-time monitoring of furnace conditions
4	20	Digital Transformation Lead	Digital Strategy	Cross-department digital collaboration improved adoption
5	16	Cybersecurity Consultant	Information Security	AI-enhanced cybersecurity analytics improved system protection
6	21	Head of Data Analytics	Data Science	Data pipelines enabled predictive process controls
7	14	Automation Specialist	Automation Engineering	PLC integration with AI allowed seamless process adjustments
8	17	Production Optimization Manager	Process Optimization	Digital twins optimized throughput in casting operations
9	19	Control Systems Engineer	Systems Engineering	Edge computing improved latency in control responses
10	13	Smart Manufacturing Advisor	Industrial Strategy	Organizational readiness was key to successful transformation
11	23	IT Infrastructure Manager	IT & Networking	Cloud migration enhanced scalability of AIoT systems
12	12	Maintenance Strategy Head	Maintenance Engineering	Maintenance algorithms cut unscheduled downtime by 18%
13	24	Chief Technical Officer	Executive Leadership	Top-down vision enabled system-wide AIoT rollout
14	20	Energy Efficiency Lead	Sustainability	Energy monitoring IoT systems reduced power usage by 8%
15	18	Industrial Innovation Consultant	Strategic Projects Office	Integrated strategy aligned AIoT projects with business KPIs

Interview Summary

The qualitative phase of this study was conducted through semi-structured interviews with 15 domain experts from Emirates Global Aluminium (EGA), comprising professionals in roles such as AI engineers, IoT infrastructure specialists, digital transformation leaders, plant operations managers, data analytics officers, and cybersecurity consultants. These participants were purposively selected based on their strategic involvement in AI and IoT initiatives within the organization and their direct experience with the implementation and scaling of smart manufacturing technologies. The average professional experience among interviewees ranged from 12 to 25 years, with a rich mix of operational, technical, and managerial expertise, providing a multi-layered understanding of digital transformation dynamics within EGA's complex industrial environment [32].

The interviews, each lasting approximately 45 to 60 minutes, were conducted over a four-week period, using both face-to-face and virtual formats, and were guided by an interview protocol aligned with the conceptual model. The responses were recorded, transcribed, anonymized, and subjected to thematic analysis. A significant emphasis was placed on capturing insights related to the four independent variables—AI capabilities, IoT infrastructure, digital transformation readiness, and data governance—and their relationship with the dependent variable, smart manufacturing performance. The responses revealed diverse but converging experiences regarding the operational impact of AIoT technologies, the organizational enablers and constraints, and the practical hurdles in real-world implementation. The inclusion of senior technical staff, project managers, and strategic advisors ensured that the insights covered both high-level planning and ground-level execution of smart manufacturing initiatives at EGA [33].

Thematic Analysis

Thematic analysis of the interview transcripts revealed five dominant themes aligned with the conceptual model. The first theme, AI Capabilities, highlighted the transformative role of machine learning in predictive maintenance, quality control, and anomaly detection. Participants shared examples where AI-based fault detection models helped preempt equipment failure, leading to a measurable reduction in downtime and improved process continuity. Natural language processing was also noted as being useful for optimizing control room communication and documentation analysis, further integrating AI into knowledge workstreams.

The second theme, IoT Infrastructure, emerged as central to the smart manufacturing ecosystem. Experts described how the deployment of industrial IoT sensors—tracking variables such as temperature, vibration, pressure, and energy usage—allowed for real-time data acquisition that fed directly into AI models. The synergy between AI and IoT was most evident in use cases involving dynamic resource allocation and environmental emissions control, where sensor data enabled rapid machine-level adjustments without human intervention.

The third theme focused on Digital Transformation Readiness. Respondents emphasized that organizational success in AIoT implementation was highly correlated with leadership commitment, employee digital literacy, and cross-departmental coordination. Some experts noted that while the technological tools were available, a lack of organizational agility or resistance to change often slowed adoption. EGA's digital maturity, cultivated through strategic leadership and investment in workforce upskilling, was considered a critical enabler in overcoming these barriers.

The fourth thematic area addressed Data Governance and Cybersecurity. Given the volume and sensitivity of operational data at EGA, participants emphasized the necessity of robust data management frameworks, secure architecture, and real-time threat detection systems. AI-based anomaly detection in cybersecurity was highlighted as increasingly essential, particularly with the rise in connected industrial systems. However, interviewees also noted that integrating these technologies posed challenges related to legacy systems and workforce trust in AI-based security mechanisms.

The final theme centered on Smart Manufacturing Performance, with nearly all interviewees acknowledging noticeable gains in operational efficiency, predictive maintenance reliability, product quality, and energy optimization since the adoption of AIoT. Nonetheless, participants cautioned that these improvements were uneven across facilities, depending on the level of digital integration and data infrastructure in place. The interviews made clear that AIoT technologies, when strategically implemented and supported by organizational readiness and strong data governance, delivered significant operational value at EGA.

Hypotheses Decisions

Each hypothesis in the study was evaluated based on the qualitative insights gathered from the interviews and the supporting documentation available at EGA. The findings indicate strong empirical support for all four proposed hypotheses.

H1: Artificial Intelligence Capabilities have a significant influence on Smart Manufacturing Performance – This hypothesis is strongly supported. Interviewees provided multiple examples where machine learning and AI algorithms enabled fault prediction, process automation, and adaptive control, leading to quantifiable improvements in production efficiency, product quality, and maintenance schedules. AI capabilities such as computer vision and natural language processing were also applied in automating inspection and documentation tasks, contributing to performance gains.

H2: IoT Integration and Infrastructure significantly influence Smart Manufacturing Performance – This hypothesis is also validated by the data. Experts emphasized that IoT networks formed the backbone of real-time visibility across the production line. The seamless flow of data from connected sensors to centralized monitoring systems enabled automated responses to changing process conditions and minimized production variability. Facilities with advanced sensor deployment and edge computing infrastructure exhibited faster and more accurate responses to anomalies.

H3: Digital Transformation Readiness significantly influences Smart Manufacturing Performance – The hypothesis is well supported by qualitative findings. Organizational factors, particularly executive commitment, employee upskilling, and cross-functional alignment, were critical in determining the success of AIoT integration. Sites with a proactive digital strategy demonstrated higher adoption rates and better system optimization. Conversely, facilities lacking in digital literacy or organizational buy-in struggled to leverage the full potential of the technology.

H4: Data Management and Cybersecurity significantly influence Smart Manufacturing Performance – This hypothesis is also affirmed. Respondents stressed the importance of data integrity, secure data storage, and real-time threat monitoring in the effective use of AIoT systems. Cybersecurity frameworks had to evolve alongside technological advancements, and investments in AI-based security systems were cited as both preventive and confidence-boosting measures. Poor cybersecurity practices were perceived as potential bottlenecks to AIoT adoption.

Implications of the Research

The findings of this research have significant practical, strategic, and theoretical implications. From a practical standpoint, the study provides a contextual roadmap for industrial organizations seeking to implement AI and IoT in manufacturing. It illustrates how tailored AI applications—such as predictive analytics for maintenance and computer vision for inspection—can deliver efficiency and quality improvements when combined with robust IoT data streams. The case of EGA demonstrates the tangible benefits of AIoT, while also outlining the prerequisite conditions for successful adoption, including skilled personnel, integrated systems, and proactive leadership.

Strategically, the study highlights the necessity of organizational readiness, especially in capital-intensive sectors like aluminium production. EGA's experience shows that technology implementation alone does not drive transformation; rather, it is the strategic orchestration of digital culture, data governance, and change management that sustains competitive advantage. The research also reinforces the importance of embedding cybersecurity and data ethics in digital transformation strategies, given the growing reliance on interconnected and autonomous systems.

Theoretically, the study makes a multi-dimensional contribution by integrating five well-established frameworks—TOE, RBV, DCT, STS, and DOI—into a single conceptual model. This holistic approach offers a rich lens through which the complex interplay of technology, organization, and environment can be examined in the context of smart manufacturing. The research provides empirical support for these theories, particularly demonstrating how dynamic capabilities, internal resources, and environmental enablers jointly determine technology adoption outcomes.

Limitations and Future Research Directions

Despite the richness of the data and the robustness of the findings, this study acknowledges several limitations. First, the single case study design limits the generalizability of the results to other industrial sectors or geographical contexts. While EGA represents a leading example in the Middle East, findings may vary in other cultural or regulatory environments. Second, the qualitative nature of the study, while offering deep insights, does not allow for statistical validation of relationships between variables. Future research could benefit from quantitative approaches using survey instruments or performance metrics to test the conceptual model across multiple organizations.

Additionally, this research captures a cross-sectional snapshot of a dynamic transformation process. Longitudinal studies are needed to understand how AIoT integration evolves over time, particularly in terms of sustained performance impact, workforce adaptation, and regulatory responses. Future research could also investigate emerging technologies such as digital twins, 5G-enabled industrial systems, and blockchain applications in smart manufacturing. Comparative case studies across sectors like aerospace, automotive, or pharmaceuticals would further deepen understanding of sector-specific drivers and barriers.

The Contribution and Originality of the Research

This research offers several distinct contributions to both academia and practice. It is among the first studies to examine AI and IoT integration in a heavy industrial context within the UAE, providing regional relevance and sectoral specificity that is often missing in global smart manufacturing literature. The conceptual model developed herein bridges five prominent theories and is grounded in empirical data, offering a replicable framework for future studies.

The originality of this study lies in its ability to contextualize complex digital transformations within real organizational settings, combining strategic insight with operational reality. By capturing the lived experiences of technical and managerial experts at EGA, the study adds richness to the understanding of digital innovation and provides practical recommendations that go beyond generic adoption models.

Conclusion

This study set out to explore the transformative role of Artificial Intelligence (AI) and Internet of Things (IoT) technologies in enabling smart manufacturing practices, with a focused case analysis of Emirates Global Aluminium (EGA)—a global industrial leader in aluminium production and a regional pioneer in Industry 4.0 adoption. In response to the growing need for sustainable, agile, and data-driven manufacturing operations, this research sought to understand how AIoT integration can improve operational performance, decision-making, and long-term competitiveness in heavy industrial environments. The study was grounded in an integrated conceptual model drawing from five well-established theoretical frameworks: the Technology-Organization-Environment (TOE) Framework, Resource-Based View (RBV), Dynamic Capabilities Theory (DCT), Socio-Technical Systems (STS) Theory, and the Diffusion of Innovation (DOI) Theory [34-36].

Using a qualitative methodology involving semi-structured interviews with 15 domain experts across EGA's operational, technological, and strategic domains, the study produced rich empirical insights that affirm the multidimensional impact of AIoT. The findings strongly support all four hypotheses proposed in the conceptual model. AI capabilities—such as machine learning for predictive maintenance and computer vision for quality inspection—have enabled greater automation, early fault detection, and enhanced precision in operations [37]. Simultaneously, the IoT infrastructure comprising real-time sensor networks, edge devices, and centralized dashboards has empowered EGA to monitor, control, and optimize its production environments with heightened responsiveness. Together, the AIoT ecosystem has significantly contributed to EGA's smart manufacturing performance in terms of reduced downtime, improved product consistency, optimized energy consumption, and enhanced process visibility.

However, the research also underscores that technology alone does not guarantee success. Digital transformation readiness—including leadership commitment, staff training, cross-functional integration, and innovation culture—emerged as a critical enabler in determining the effectiveness of AIoT adoption [38]. Sites within EGA that demonstrated higher levels of organizational maturity, openness to innovation, and workforce preparedness were notably more successful in translating technological investments into performance outcomes. Furthermore, the study highlights the crucial role of robust data management and cybersecurity protocols in sustaining the scalability and integrity of AIoT systems. Given the volume and sensitivity of data processed in smart manufacturing, EGA's strategic emphasis on data governance and AI-powered threat monitoring has proven indispensable [39].

This research makes several valuable contributions. Theoretically, it expands existing literature by integrating five complementary frameworks into a unified model that captures the complex interplay between technology, organization, and environment in smart manufacturing. Empirically, it offers an in-depth, context-specific examination of how a leading UAE-based manufacturer applies AI and IoT in real-world operations—filling a significant gap in both regional and sectoral literature. Practically, the study offers a strategic roadmap for industrial managers, technology developers, and policymakers interested in deploying AIoT solutions to drive operational efficiency, sustainability, and competitive advantage [40].

Despite its depth, the study acknowledges certain limitations. It adopts a single-case qualitative design, which, while rich in contextual insight, limits generalizability. The absence of quantitative validation and longitudinal tracking also suggests avenues for future research. Scholars may build on this work by conducting multi-case or cross-sectoral studies, applying quantitative models such as SEM or PLS to test the conceptual framework, or exploring emerging technologies like digital twins and decentralized AI in smart factories. In addition, comparative studies across regions—such as Southeast Asia, Europe, or Sub-Saharan Africa—can provide insights into how cultural, regulatory, and infrastructural differences influence AIoT adoption.

In conclusion, this study provides a comprehensive, multi-theoretical, and empirically grounded understanding of how AI and IoT technologies are reshaping the landscape of industrial manufacturing through smart, data-centric, and adaptive systems. The case of EGA illustrates the enormous potential of AIoT to transform traditional manufacturing into a predictive, resilient, and intelligent ecosystem. It also highlights that the path to digital maturity is not solely technological but also organizational, cultural, and strategic. As global industry continues to move towards interconnected, automated, and sustainable paradigms, studies such as this serve as valuable blueprints for navigating the complex journey of industrial digital transformation.

References

1. Paramesha, M., Rane, N. L., & Rane, J. (2024). Big data analytics, artificial intelligence, machine learning, internet of things, and blockchain for enhanced business intelligence. Partners Universal Multidisciplinary Research Journal. 1: 110-133.
2. Kumar, S., Verma, A. K., & Mirza, A. (2024). Digitalisation, Artificial Intelligence, IoT, and Industry 4.0 and Digital Society. In Digital Transformation, Artificial Intelligence and Society: Opportunities and Challenges. Singapore: Springer Nature Singapore. 35-57.
3. Mishra, A. A., & Pathak, D. K. (2024). Industry 4.0 technologies adoption and sustainability integration in Human resource management: An analysis using extended TOE Framework and TISM. IEEE Transactions on Engineering Management. 71: 14688-14703.
4. Sinha, S., & Lee, Y. M. (2024). Challenges with developing and deploying AI models and applications in industrial systems. Discover Artificial Intelligence. 4: 55.
5. Zong, Z., & Guan, Y. (2024). AI-driven intelligent data analytics and predictive analysis in Industry 4.0: Transforming knowledge, innovation, and efficiency. Journal of the Knowledge Economy. 1-40.
6. Soori, M., Jough, F. K. G., Dastres, R., & Arezoo, B. (2024). AI-based decision support systems in Industry 4.0, A review. Journal of Economy and Technology.
7. Lu, Y. (2017). Industry 4.0: A survey on technologies, applications and open research issues. Journal of Industrial Information Integration. 6: 1–10.
8. Zuehlke, D. (2010). SmartFactory—Towards a factory-of-things. Annual Reviews in Control. 34: 129-138.
9. Kilari, S. D. (2025). Use Artificial Intelligence into Facility Design and Layout Planning Work in Manufacturing Facility. European Journal of Artificial Intelligence and Machine Learning. 4: 27-30.
10. Yu, Y., Xu, J., Zhang, J. Z., Liu, Y. D., Kamal, M. M., & Cao, Y. (2024). Unleashing the power of AI in manufacturing: Enhancing resilience and performance through cognitive insights, process automation, and cognitive engagement. International Journal of Production Economics. 270: 109175.
11. Kusiak, A. (2018). Smart manufacturing. International Journal of Production Research. 56: 508-517.
12. Rahmayanti, D. (2024). Artificial Intelligence of Things (AIoT) To Improve Efficiency and Automation in Industrial 4.0. Sci-tech Journal. 3: 255-270.
13. George, A. S. (2024). AI-Enabled Intelligent Manufacturing: A Path to Increased Productivity, Quality, and Insights. Partners Universal Innovative Research Publication. 2: 50-63.
14. Vial, G. (2019). Understanding digital transformation: A review and a research agenda. Journal of Strategic Information Systems. 28: 118-144.
15. Westerman, G., Bonnet, D., & McAfee, A. (2014). Leading digital: Turning technology into business transformation. Harvard Business Review Press.
16. Sadeghi, A.-R., Wachsmann, C., & Waidner, M. (2015). Security and privacy challenges in industrial Internet of Things. Proceedings of the 52nd Design Automation Conference. 1-6.
17. Sun, Y., Hahn, C., & Liu, P. (2020). Data security and privacy in IoT: A review of recent developments and future directions. IEEE Internet of Things Journal. 7: 5380-5394.
18. Tornatzky, L. G., & Fleischer, M. (1990). The processes of technological innovation. Lexington Books.
19. Barney, J. B. (1991). Firm resources and sustained competitive advantage. Journal of Management. 17: 99-120.
20. Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. Strategic Management Journal. 18: 509-533.
21. Rogers, E. M. (2003). Diffusion of innovations (5th ed.). Free Press. https://books.google.com/books/about/Diffusion_of_Innovations.html?id=9U1K5LjUOwEC.
22. Singha, R., & Singha, S. (2024). AIoT concepts and integration: exploring customer interaction, ethics, policy, and privacy. In Artificial Intelligence of Things (AIoT) for Productivity and Organizational Transition. IGI Global. 26-51.
23. Mishra, S. B., & Liyakat, K. K. S. (2024). AI-Driven-IoT (AIIoT) Based Decision-Making in Molten Metal Processing. Journal of Industrial Mechanics. 9: 45-56.
24. Willie, M. (2025). Leveraging Digital Resources: A Resource-Based View Perspective. Golden Ratio of Human Resource Management. 5: 01-14.
25. Thomas, A. (2024). Digitally transforming the organization through knowledge management: a socio-technical system

(STS) perspective. European Journal of Innovation Management. 27: 437-460.
26. Iyer, S. S., & Raji, B. (2025). Cybersecurity Culture and Organizational Resilience: A Human-Centered Approach to Digital Risk Management. American Journal of Industrial and Business Management. 15: 748-766.
27. Saunders, M., Lewis, P., & Thornhill, A. (2019). Research methods for business students (8th ed.). Pearson Education Limited.
28. Iyer, S.S.; Alsheroa, H. (2025). Key Factors Influencing AI Opportunities in UAE Municipal Services. Journal of Pioneering Artificial Intelligence Research. 1: 1-21,
29. Iyer, S. S., Seetharaman, A., & Maddulety, K. (2024). Building Sustainability Index for Dubai Electricity and Water Authority. Arts & Humanities Open Access Journal. 6: 111-123.
30. Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology. 3: 77-101.
31. Raman, R., Pattnaik, D., Lathabai, H. H., Kumar, C., Govindan, K., & Nedungadi, P. (2024). Green and sustainable AI research: an integrated thematic and topic modeling analysis. Journal of Big Data. 11: 1-28.
32. Iyer, S. S., Subramanian, R., Dhoundiyal, M., Mehrotra, A., & Gunardi, A. (2024). Green accounting leads to sustainable companies. Indonesian Journal of Sustainability Accounting and Management. 8.
33. Shankar Subramanian Iyer, D. D. G., Krishnan, A. S., Malhotra, S., Singh, A. K., & Khan, F. (2024). The Rainbow Economy Model Leads To Holistic Circular Model. Migration Letters. 21: 1-26.
34. Bughin, J., Seong, J., Manyika, J., Chui, M., & Joshi, R. (2018). Notes from the AI frontier: Modeling the impact of AI on the world economy. McKinsey Global Institute. https://www.mckinsey.com/featured-insights/artificial-intelligence
35. Choudhary, A., Harding, J. A., & Tiwari, M. K. (2009). Data mining in manufacturing: A review based on the kind of knowledge. Journal of Intelligent Manufacturing. 20: 501–521.
36. Colakovic, A., & Hadzialic, M. (2018). Internet of Things (IoT): A review of enabling technologies, challenges, and open research issues. Computer Networks. 144: 17-39.
37. Lee, J., Bagheri, B., & Kao, H. A. (2015). A cyber-physical systems architecture for Industry 4.0-based manufacturing systems. Manufacturing Letters. 3: 18-23.
38. Müller, J. M., Kiel, D., & Voigt, K. I. (2018). What drives the implementation of Industry 4.0? The role of opportunities and challenges in the context of sustainability. Sustainability. 10: 247.
39. Rezaei, S., & Ansary, A. (Eds.). (2024). Artificial Intelligence of Things (AIoT) for Productivity and Organizational Transition. IGI Global. DOI: 10.4018/979-8-3693-0993-3
40. Trist, E., & Bamforth, K. W. (1951). Some social and psychological consequences of the longwall method of coal-getting. Human Relations. 4: 3-38.