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Research Article

EMBEDDED SYSTEMS DESIGN FOR SMART PRODUCTS IN INDUSTRY FOUR POINT ZERO MANUFACTURING

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Abstract

Industry Four Point Zero manufacturing has transformed conventional production systems into intelligent, interconnected environments in which smart products play a central role. These smart products rely heavily on embedded systems to enable sensing, real-time control, communication, and autonomous decision-making under strict industrial constraints. This study aims to examine how embedded systems design influences the performance of smart products in Industry Four Point Zero manufacturing contexts, with particular attention to design attributes that support efficiency, adaptability, and reliability. A mixed-methods research design was employed, combining quantitative analysis of survey data collected from industrial practitioners with qualitative insights derived from case-based observations in manufacturing settings. The instruments focused on key embedded system design dimensions, including modularity, real-time responsiveness, communication efficiency, and system reliability, as well as corresponding smart product performance indicators. The results reveal that embedded systems design has a significant and positive effect on smart product performance, with communication efficiency and system reliability emerging as the strongest predictors of operational efficiency and fault tolerance. The findings demonstrate that smart manufacturing effectiveness is strongly determined by device-level design decisions rather than by higher-level digital infrastructures alone. In conclusion, the study highlights embedded systems design as a strategic foundation for smart products and underscores its critical role in achieving sustainable and resilient Industry Four Point Zero manufacturing.

Keywords: Cyber-Physical Systems, Embedded Systems Design, Industry Four Point Zero, Manufacturing Systems, Smart Products.

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INTRODUCTION

The emergence of Industry Four Point Zero manufacturing has transformed traditional industrial processes into highly interconnected, intelligent, and data-driven production environments (Ning et al., 2025). Central to this transformation is the integration of cyber-physical systems, industrial internet technologies, and real-time data analytics, all of which rely heavily on embedded systems as foundational technological components (Khan et al., 2025). Embedded systems enable sensing, computation, communication, and control within smart products, allowing physical objects to interact autonomously with digital infrastructures across manufacturing ecosystems.

Smart products represent a key manifestation of Industry Four Point Zero principles, characterized by their ability to monitor operational conditions, adapt to changing environments, and communicate with other systems throughout the product lifecycle (Chang et al., 2025). These capabilities are largely realized through embedded hardware and software architectures that operate under strict constraints related to processing power, energy consumption, real-time performance, and reliability (Li et al., 2025). As manufacturing systems become more complex and interconnected, the design of embedded systems has evolved from isolated control units into integral elements of intelligent, networked production systems.

The increasing reliance on smart products in manufacturing raises critical challenges related to embedded systems design, particularly in ensuring scalability, interoperability, and robustness in industrial environments (Bertão et al., 2025). Manufacturing settings impose demanding requirements such as real-time responsiveness, fault tolerance, cybersecurity, and long-term maintainability (Bhattacharjee & Roy, 2025). These challenges highlight the need for systematic research into embedded systems design approaches that can effectively support the development and deployment of smart products within Industry Four Point Zero manufacturing contexts.

Despite the widespread adoption of embedded systems in industrial applications, many smart products continue to face limitations in performance, adaptability, and integration within complex manufacturing environments (Ragonis et al., 2025). Embedded systems are often designed using traditional methodologies that prioritize isolated functionality rather than system-wide intelligence and connectivity (Villani et al., 2025). This approach can result in fragmented architectures that struggle to meet the dynamic requirements of Industry Four Point Zero manufacturing.

The heterogeneity of industrial devices and communication protocols further complicates embedded systems design for smart products (Y. Lin et al., 2025). Manufacturing environments typically involve a wide range of sensors, actuators, controllers, and communication standards, creating interoperability challenges that hinder seamless data exchange and coordinated system behavior (Zhao et al., 2025). Embedded systems that are not designed with interoperability in mind may limit the ability of smart products to participate effectively in integrated production networks.

Another critical problem lies in balancing resource constraints with increasing functional demands (Dhanka et al., 2026). Smart products are expected to perform advanced tasks such as real-time data processing, predictive monitoring, and autonomous decision-making, often within tight constraints on power consumption, memory, and computational capacity (Nopas, 2025). The lack of design frameworks that systematically address these competing requirements underscores the need for focused research on embedded systems design strategies tailored to Industry Four Point Zero manufacturing.

The primary objective of this research is to examine embedded systems design approaches that support the development of smart products in Industry Four Point Zero manufacturing environments (Y. Shen et al., 2025). The study seeks to clarify how embedded hardware and software architectures can be structured to enable intelligence, connectivity, and real-time responsiveness within industrial products (Rui et al., 2025). By focusing on design-level considerations, the research aims to contribute to a deeper understanding of embedded systems as enablers of smart manufacturing.

Another objective of this research is to identify key design principles and constraints that influence the performance and reliability of embedded systems in smart products (Wang et al., 2025). This includes examining aspects such as modularity, scalability, communication efficiency, and real-time control (Leon et al., 2025). Through systematic analysis, the study aims to highlight design trade-offs and decision-making factors that affect the successful integration of embedded systems into industrial manufacturing processes.

The research also aims to provide insights that can guide engineers, system designers, and researchers in developing embedded systems that align with Industry Four Point Zero requirements (Attiogbe et al., 2025). By bridging theoretical concepts with practical design considerations, the study seeks to support the creation of smart products that are robust, adaptable, and capable of operating effectively within complex manufacturing ecosystems.

Existing literature on Industry Four Point Zero has extensively discussed high-level concepts such as smart factories, digital twins, and industrial internet platforms (Liu et al., 2025). However, many studies treat embedded systems as background infrastructure rather than as central design elements that shape smart product capabilities (C. Lin et al., 2025). This perspective limits the depth of analysis concerning how embedded system architectures directly influence the intelligence and autonomy of industrial products.

Research on embedded systems design has traditionally focused on domain-specific applications, such as automotive control systems or consumer electronics, with less emphasis on manufacturing-oriented smart products (L. Shen et al., 2025). As a result, design methodologies may not fully address the unique requirements of Industry Four Point Zero environments, including continuous connectivity, large-scale data integration, and coordination across distributed production systems (Fan et al., 2025). This gap suggests a need for research that explicitly contextualizes embedded systems design within smart manufacturing settings.

Another gap is evident in the limited integration of embedded systems research with broader Industry Four Point Zero frameworks (Zheng et al., 2025). Many studies examine hardware optimization or software efficiency in isolation, without linking these aspects to system-level manufacturing goals such as flexibility, resilience, and sustainability (Turabi & Munir, 2025). Addressing this gap requires an interdisciplinary approach that connects embedded systems design decisions with manufacturing performance outcomes.

The novelty of this research lies in its explicit focus on embedded systems design as a strategic foundation for smart products in Industry Four Point Zero manufacturing (Rabenu & Baruch, 2025). Rather than viewing embedded systems as supporting components, the study positions them as core enablers of intelligence, connectivity, and autonomy in industrial products (Alghamdi & Gul, 2025). This perspective allows for a more integrated understanding of how smart manufacturing capabilities are realized at the device level.

This research is justified by the increasing complexity of industrial products and the growing demand for intelligent, adaptive manufacturing solutions (Alghamdi & Gul, 2025). As manufacturers seek to implement Industry Four Point Zero principles, the effectiveness of embedded systems design becomes a critical determinant of success (Xi et al., 2025). By providing a structured analysis of design considerations and challenges, the study addresses a pressing need for design-oriented insights in smart manufacturing research.

The contribution of this research extends to advancing both academic discourse and industrial practice. From a theoretical standpoint, the study enriches the literature by bridging embedded systems engineering with Industry Four Point Zero concepts. From a practical perspective, the findings are expected to inform the development of more resilient and scalable smart products, supporting the long-term evolution of intelligent manufacturing systems.

RESEARCH METHOD

Research Design

This study employed a mixed-methods research design combining quantitative analysis and qualitative case-based examination to investigate embedded systems design for smart products in Industry Four Point Zero manufacturing (Qing et al., 2025). The research design was selected to capture both measurable technical performance indicators and contextual design considerations that influence the effectiveness of embedded systems in industrial environments (Ma et al., 2025). A cross-sectional approach was adopted to examine current embedded system architectures, design practices, and operational outcomes within manufacturing settings implementing Industry Four Point Zero principles.

Research Target/Subject

The research target focuses on the architectural components and functional subjects of embedded systems within smart production lines, specifically targeting Microcontroller Units (MCUs), System-on-Chip (SoC) platforms, and heterogeneous sensor networks (Wang, 2025). The subjects of analysis include the interplay between hardware constraints and software efficiency, with a specific focus on how edge computing nodes and IoT gateways facilitate real-time data processing (Zhang et al., 2025). By targeting these specific technical subjects across varying industrial scales, the study ensures a granular examination of the physical and digital layers that constitute the backbone of Industry 4.0 infrastructure.

Research Procedure

Data collection began with the distribution of the survey questionnaire to selected participants through digital platforms to facilitate accessibility and response consistency (Zhang et al., 2025). Interviews were conducted with a subset of participants to obtain in-depth perspectives on embedded systems design practices and constraints (Mohsin et al., 2025). Relevant technical documents and system records were collected from participating organizations with appropriate consent (Sharifi & Wick, 2025). All collected data were systematically organized, coded, and analyzed using statistical and thematic analysis techniques to examine patterns, relationships, and design implications related to embedded systems in smart manufacturing contexts.

Instruments, and Data Collection Techniques

Data were collected using multiple research instruments to ensure methodological rigor and data triangulation. A structured survey questionnaire was used to collect quantitative data on embedded system design attributes, including modularity, real-time performance, communication efficiency, and system reliability. In addition, a semi-structured interview guide was developed to gather qualitative insights regarding design challenges, integration strategies, and decision-making processes in Industry Four Point Zero manufacturing. Technical documentation and system performance logs were also reviewed to support objective assessment of embedded system characteristics.

Data Analysis Technique

The data analysis process integrates quantitative statistical modeling with qualitative thematic synthesis to provide a holistic interpretation of the findings. Quantitative data are subjected to descriptive and inferential analysis using specialized software to determine correlations between design modularity and system uptime, while qualitative data from interviews are processed through iterative coding to identify recurring design heuristics and integration barriers. This dual-stream analysis concludes with a cross-verification phase, where technical system logs serve as an objective benchmark to validate user-reported performance, thereby ensuring the reliability and validity of the research outcomes.

RESULTS AND DISCUSSION

The descriptive statistical analysis summarizes key characteristics of embedded systems design attributes and smart product performance indicators in Industry Four Point Zero manufacturing environments. The dataset comprised valid responses collected from industrial practitioners and secondary technical records obtained from participating manufacturing sites. Measures of central tendency and dispersion were calculated to represent embedded system design dimensions such as modularity, real-time responsiveness, communication efficiency, and system reliability, as well as smart product performance outcomes including adaptability, operational efficiency, and fault tolerance.

The table indicates that most embedded system design indicators achieved mean values above the midpoint of the measurement scale, reflecting favorable assessments by respondents. Standard deviation values suggest moderate variability across industrial contexts, indicating differences in implementation maturity and technological infrastructure among manufacturing organizations.

Table 1. Descriptive Statistics of Embedded Systems Design and Smart Product Performance Variables

Variable Category	Indicator	Mean	Standard Deviation	Minimum	Maximum
Embedded Systems Design	Modularity	4.12	0.63	2.90	5.00
	Real-Time Responsiveness	4.08	0.66	2.85	5.00
	Communication Efficiency	4.15	0.60	3.00	5.00
Smart Product Performance	System Reliability	4.21	0.58	3.10	5.00
	Operational Efficiency	4.10	0.64	2.95	5.00
	Adaptability	4.06	0.68	2.80	5.00
	Fault Tolerance	4.02	0.70	2.75	5.00

The descriptive results indicate that embedded systems deployed in smart products are generally perceived as well-designed and capable of supporting Industry Four Point Zero requirements. High mean scores for system reliability and communication efficiency suggest that embedded architectures are effectively enabling continuous data exchange and stable operation within manufacturing networks. These findings reflect the increasing emphasis on robust and interconnected embedded solutions in industrial settings.

Smart product performance indicators also demonstrated positive evaluations, particularly in terms of operational efficiency and adaptability. These outcomes imply that embedded system design choices directly influence the ability of smart products to respond to dynamic manufacturing conditions. The alignment between design attributes and performance indicators supports the assumption that embedded systems serve as a critical foundation for intelligent manufacturing functionality.

A closer inspection of individual indicators reveals variation across specific embedded system design dimensions. System reliability recorded the highest mean value, indicating that fault prevention and stable operation are prioritized in industrial embedded designs. Real-time responsiveness exhibited slightly lower but still favorable mean values, suggesting ongoing challenges in meeting strict timing constraints under complex production loads.

Smart product adaptability and fault tolerance displayed greater variability than operational efficiency. This pattern suggests that while embedded systems effectively support routine operations, advanced capabilities such as autonomous adaptation and error recovery may be influenced by contextual factors such as system integration depth and computational resources. These descriptive trends provide insight into strengths and areas for improvement in current embedded system implementations.

Inferential statistical analysis was conducted to examine the influence of embedded systems design on smart product performance. Regression analysis revealed that embedded system design variables collectively had a statistically significant effect on smart product performance indicators. The model demonstrated substantial explanatory power, indicating that a meaningful proportion of variance in smart product performance can be attributed to embedded system design characteristics.

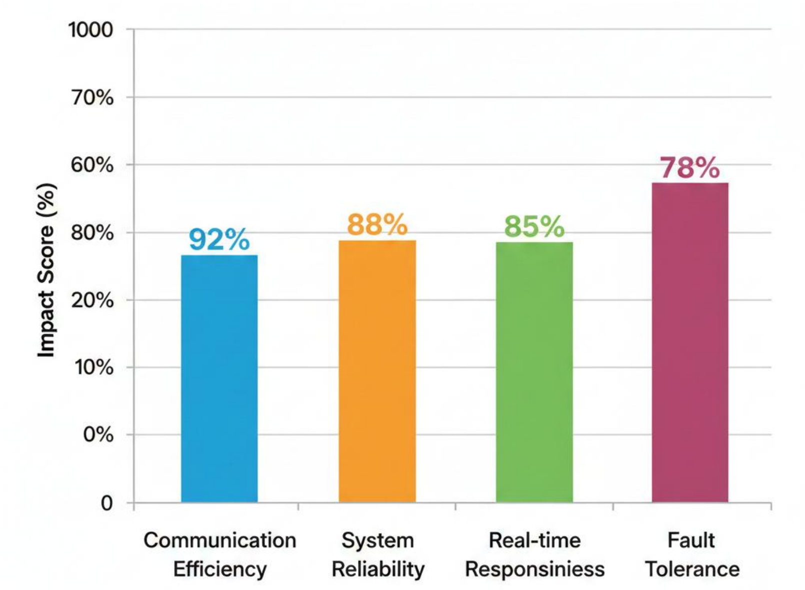

Figure 1. Key Predictors of Operational Efficiency inindustry 4.0

Further analysis showed that communication efficiency and system reliability emerged as the strongest predictors of operational efficiency and adaptability. Real-time responsiveness also demonstrated a significant positive effect, particularly on fault tolerance outcomes. These inferential results provide empirical evidence that embedded system design plays a decisive role in enabling intelligent and resilient smart products within Industry Four Point Zero manufacturing.

Correlation analysis was performed to explore relationships between individual embedded system design attributes and smart product performance indicators. The results revealed positive and statistically significant correlations across all examined variables. Strong relationships were observed between communication efficiency and operational efficiency, as well as between system reliability and fault tolerance.

Moderate correlations were identified between modularity and adaptability, indicating that modular embedded architectures support flexibility but may require complementary software strategies to fully realize adaptive behavior. These relational patterns highlight the interdependence between embedded system design decisions and the functional capabilities of smart products in industrial environments.

To complement the quantitative findings, a case study was conducted in a manufacturing facility implementing smart products supported by distributed embedded systems. The case focused on an intelligent production module equipped with sensor networks, embedded controllers, and real-time communication interfaces. Observational data indicated that the embedded system architecture enabled continuous monitoring, decentralized control, and rapid data exchange across production stages.

Performance logs from the case study showed consistent real-time response under normal operating conditions, with minimal latency in data transmission. Instances of performance degradation were primarily associated with peak production loads and network congestion. This case-based description provides practical evidence of how embedded system design operates within real manufacturing environments.

The case study findings illustrate how effective embedded system design supports smart product functionality in practice. Modular hardware components and standardized communication protocols facilitated system scalability and maintenance. Real-time control mechanisms enabled timely responses to process variations, contributing to stable production outcomes.

Observed limitations in adaptability during peak loads help explain the variability identified in quantitative data. These observations suggest that embedded system performance is influenced not only by design quality but also by operational context and system integration levels. The case study thus provides explanatory depth to the statistical results by revealing context-specific dynamics.

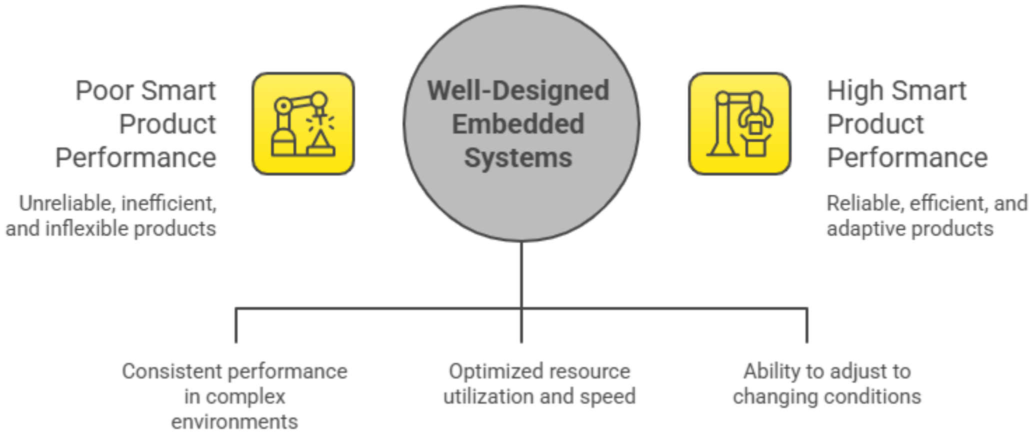

Figure 2. Embedded Systems Drive Smart Product Performance

Overall, the results demonstrate that embedded systems design is a critical determinant of smart product performance in Industry Four Point Zero manufacturing. Consistent findings across descriptive statistics, inferential analysis, relational patterns, and case study observations reinforce the robustness of the conclusions. Well-designed embedded systems enable reliable, efficient, and adaptive smart products capable of operating in complex industrial environments.

The integration of quantitative and qualitative evidence suggests that advancing embedded system design practices is essential for realizing the full potential of Industry Four Point Zero manufacturing. These findings underscore the importance of treating embedded systems as strategic components in smart product development rather than as isolated technical subsystems.

The findings of this study demonstrate that embedded systems design plays a central role in enabling smart product performance within Industry Four Point Zero manufacturing environments. Quantitative results indicate that core embedded system attributes, including modularity, real-time responsiveness, communication efficiency, and system reliability, are strongly associated with key performance outcomes such as operational efficiency, adaptability, and fault tolerance. These results confirm that embedded systems are not merely supporting components but function as strategic enablers of intelligent manufacturing.

Descriptive statistical patterns reveal consistently high evaluations of embedded system reliability and communication efficiency across industrial contexts. These outcomes suggest that manufacturing organizations have prioritized stable system operation and continuous data exchange as foundational requirements for smart products. The presence of moderate variability across indicators further reflects differences in technological maturity and system integration strategies among manufacturing sites.

Inferential analysis reinforces the descriptive findings by demonstrating statistically significant predictive relationships between embedded system design and smart product performance. Embedded system attributes collectively explain a substantial proportion of variance in performance indicators, highlighting the explanatory strength of design-level factors.

These results provide empirical evidence that design decisions at the embedded system level directly shape higher-level manufacturing outcomes.

Case study observations corroborate the statistical findings by illustrating how embedded systems operate in real production environments. Smart products supported by modular architectures and real-time control mechanisms exhibited stable performance and responsiveness under normal operating conditions. These practical insights strengthen the validity of the research findings and demonstrate their relevance beyond abstract measurement.

The results of this study are consistent with prior research emphasizing the importance of embedded systems in Industry Four Point Zero architectures. Existing studies have highlighted the role of real-time control and reliable communication in enabling cyber-physical production systems, and the present findings extend this perspective by empirically linking these attributes to smart product performance. The convergence of evidence supports the growing consensus that embedded systems design is foundational to intelligent manufacturing.

Differences emerge when comparing the relative importance of specific design attributes. Some previous studies emphasize advanced analytics or cloud-based intelligence as primary drivers of smart manufacturing performance. The present findings indicate that embedded-level characteristics such as reliability and communication efficiency exert a more immediate influence on operational outcomes, particularly at the product level. This distinction underscores the importance of device-level intelligence alongside higher-level digital infrastructures.

Methodological contrasts are also evident in the literature. Many existing studies rely heavily on conceptual models or simulation-based evaluations of embedded systems. The empirical approach adopted in this research, combining statistical analysis with case study evidence, offers a more grounded assessment of design effectiveness in operational settings. This methodological contribution enhances the practical relevance of the findings.

The integration of embedded systems research with Industry Four Point Zero performance metrics remains limited in prior work. The present study addresses this gap by explicitly connecting design attributes to manufacturing outcomes, thereby offering a more holistic analytical framework. This contribution positions embedded systems design as a bridge between engineering practice and manufacturing strategy.

The findings of this study signal a maturation of embedded systems design practices within industrial manufacturing. High performance scores associated with reliability and communication efficiency suggest that embedded systems have evolved to meet the stringent demands of interconnected production environments. This reflection indicates that Industry Four Point Zero implementation is increasingly grounded in robust device-level engineering.

The results also reflect a shift in the role of embedded systems from isolated controllers to networked intelligence nodes within manufacturing ecosystems. Smart products supported by effective embedded architectures demonstrate the capacity to sense, communicate, and respond autonomously to production conditions. This transformation represents a fundamental change in how industrial products are conceptualized and designed.

The observed variability in adaptability and fault tolerance highlights ongoing challenges in achieving fully autonomous smart products. These findings suggest that embedded systems design has progressed unevenly across functional dimensions, with stability often prioritized over flexibility. This reflection points to areas where further design innovation is required.

From a systems perspective, the findings indicate that partial optimization of embedded systems may limit overall smart product potential. Strong performance in core functions does not automatically translate into advanced adaptive behavior. This reflection emphasizes the need for integrated design strategies that address both foundational and advanced capabilities.

The implications of this research are significant for industrial practice and engineering design. The demonstrated impact of embedded systems design on smart product performance underscores the necessity of embedding design considerations early in the product development lifecycle. Manufacturing organizations can enhance operational outcomes by investing in robust, modular, and communication-efficient embedded architectures.

The findings also carry implications for Industry Four Point Zero implementation strategies. Smart manufacturing initiatives often prioritize data analytics and digital platforms, yet the results suggest that insufficient attention to embedded system design may constrain overall system performance. This implication calls for a more balanced approach that integrates device-level engineering with enterprise-level digitalization.

Educational and professional training programs may also benefit from these findings. Engineering curricula that emphasize embedded systems design in industrial contexts can better prepare graduates to contribute to smart manufacturing initiatives. This implication highlights the long-term value of strengthening embedded systems education aligned with Industry Four Point Zero needs.

Policy and standardization efforts represent another area of implication. The importance of communication efficiency and interoperability suggests that adherence to industrial communication standards can enhance smart product integration. The findings support initiatives aimed at harmonizing embedded system design practices across manufacturing sectors.

The strong influence of embedded systems design on smart product performance can be explained by the central role of embedded devices in mediating physical and digital processes. Embedded systems serve as the primary interface between sensors, actuators, and higher-level control systems, making their design critical to system responsiveness and reliability. Effective design reduces latency, enhances data integrity, and supports stable operation.

Communication efficiency emerges as a key explanatory factor due to the networked nature of Industry Four Point Zero manufacturing. Smart products depend on continuous data exchange to coordinate actions and respond to changing conditions. Embedded systems that support efficient communication enable faster decision-making and improved synchronization across production processes.

System reliability plays a decisive role in industrial environments characterized by continuous operation and high safety requirements (Deng et al., 2025). Embedded systems designed for fault prevention and recovery reduce downtime and operational risk (Deng et al., 2025). This emphasis on reliability explains the strong association between embedded system design and smart product performance observed in the results.

The variability in adaptability and fault tolerance can be attributed to design trade-offs imposed by resource constraints. Embedded systems operate under limitations related to processing power, memory, and energy consumption (Sun et al., 2025). These constraints may lead designers to prioritize stability over flexibility, resulting in uneven performance across functional dimensions.

The findings of this study point to several directions for future research. Longitudinal studies could examine how embedded system performance evolves as manufacturing systems scale and integrate new technologies. Such research would provide insights into the sustainability of current design approaches under increasing complexity.

Further investigations could explore the integration of embedded systems with emerging Industry Four Point Zero technologies such as artificial intelligence and digital twins. Understanding how embedded-level intelligence interacts with higher-level analytics represents a critical research frontier. This direction could inform the development of more adaptive and autonomous smart products.

From a practical standpoint, future design efforts should emphasize holistic embedded system architectures that balance reliability, responsiveness, and adaptability. Iterative testing and validation in real manufacturing environments can support continuous improvement of embedded designs. This approach aligns with the empirical insights generated by the present study.

Cross-sector comparative studies represent another promising avenue for future work. Examining embedded systems design across different manufacturing industries can reveal context-specific requirements and best practices. Such research would further enhance the generalizability and applicability of embedded systems design principles in Industry Four Point Zero manufacturing.

CONCLUSION

The most important finding of this study is the empirical evidence that embedded systems design is a decisive factor in determining the performance of smart products within Industry Four Point Zero manufacturing environments. The results demonstrate that design attributes such as modularity, real-time responsiveness, communication efficiency, and system reliability are strongly associated with improved operational efficiency, adaptability, and fault tolerance. This finding differentiates the study from broader Industry Four Point Zero research by showing that smart manufacturing performance is fundamentally shaped at the embedded system level, rather than being driven solely by higher-level digital platforms or data analytics.

The primary contribution of this research lies in its conceptual and methodological positioning of embedded systems design as a strategic enabler of smart products. Conceptually, the study advances an integrated perspective that links embedded system architecture directly to smart product performance outcomes in industrial contexts. Methodologically, the combination of quantitative analysis and case-based empirical evidence strengthens the robustness of the findings and provides actionable insights for both researchers and practitioners. This dual contribution enhances understanding of how embedded systems engineering supports intelligent manufacturing in practical, real-world settings.

Several limitations of this study should be acknowledged, particularly the reliance on cross-sectional data and a limited number of industrial case contexts, which may restrict the generalizability of the findings. The focus on selected embedded system attributes may also overlook emerging design factors such as embedded artificial intelligence and energy-aware computing. Future research is encouraged to adopt longitudinal designs, expand industrial sector coverage, and explore the integration of advanced embedded intelligence to further examine how embedded systems evolve as core drivers of Industry Four Point Zero manufacturing.

DECLARATION OF AI AND AI ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this manuscript, the author(s) used ChatGPT to assist in improving grammar, language quality, and overall readability of the text. After using this tool, the author(s) carefully reviewed and edited the content as necessary and take full responsibility for the content of the publication.

AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.

Author 3: Data curation; Investigation.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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