

Implementation of artificial intelligence project, quality internal and external supply chain integration, responsiveness for operational performance in manufacturing

Zeplin Jiwa Husada Tarigan^{a*}, Maria Natalia Damayanti Maer^a, Mariana Ing Malelak^a, Sautma Ronni Basana^a, Hotlan Siagian^a and Zarul Azhar bin Nasir^b

^aSchool Business Management, Petra Christian University, Surabaya, Indonesia

^bFaculty of Business and Management, Universiti Teknologi MARA Perak Branch, Malaysia

ABSTRACT

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This paper analyzes the effect of Artificial Intelligence (AI) implementation projects on the operational performance of manufacturing companies in Indonesia, considering the mediating role of quality internal integration, quality external integration, and supply chain responsiveness. This study uses a quantitative research approach, utilizing a survey method, with 109 manufacturing companies in Java and Bali that have adopted AI technology in their production processes. Data processing was carried out using the Partial Least Squares (PLS) approach. The results indicate that the AI implementation project has a significant impact on both internal quality integration and external quality integration but does not directly affect supply chain responsiveness or operational performance. Quality internal integration is proven to be a key variable that significantly affects quality external integration, supply chain responsiveness, and operational performance. Meanwhile, quality external integration has a significant effect on supply chain responsiveness but not on operational performance directly. Additionally, supply chain responsiveness has been proven to positively contribute to improving operational performance. The conceptual model developed in this study successfully demonstrates a multi-layered influence path from AI implementation project to operational performance through quality integration and supply chain responsiveness. This study highlights the importance of synergy between AI technology and internal and externally integrated quality management systems in achieving operational excellence in the manufacturing sector. These findings expand the theoretical understanding of the strategic role of AI in the context of supply chain and operational quality.

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1. Introduction

The use of technology by manufacturing companies is a necessity for increasing competitiveness by enhancing efficiency and effectiveness (Wamba-Taguimdje et al., 2020; Mukherjee et al., 2024). Artificial Intelligence (AI) is a widely discussed technology that benefits the manufacturing industry, enabling companies to become more innovative manufacturers (Leoni et al., 2022). A project of AI is a computer program designed to replace workers because it can imitate human intelligence and complete work quickly and accurately (Younis et al., 2022; Paesano, 2023). The implementation of AI in manufacturing companies brings innovation, leading to changes in business processes and production that enable products to be produced according to customer demand (Kumar et al., 2023). AI can transform the overall manufacturing work system and impact performance improvements (Leoni et al., 2022; Upadhyay et al., 2023). Manufacturing companies can increase productivity, thereby reducing production costs associated with creating products. AI can be applied to identify processes that are automatically selected or selected by equipment to improve product quality (Abadie et al., 2023; Chen et al., 2022; Mota et al., 2025). Manufacturing companies implement automation systems that utilize AI to minimize machine downtime. AI can significantly replace human work with automated machines (Kaplan & Haenlein, 2019). Businesses are striving to adopt AI

* Corresponding author

E-mail address zeplin@petra.ac.id (Z.J.H. Tarigan)

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to drive innovation within companies and enhance design flexibility (Upadhyay et al., 2023). A company's ability to adopt the latest technology allows for a rapid response to environmental and market changes by leveraging platform integration, agility, and a robust digital ecosystem (Marjerison et al., 2025). AI in companies can optimize supply chain functions for improved decision-making and sustainability (Serrano-Torres et al., 2025).

AI has been widely applied in companies to provide high added value to products and processes, thereby improving company performance (Chen et al., 2022). Generative AI capabilities have been applied in manufacturing companies to enhance human resource productivity and support demand and supply planning (Al-Khatib et al., 2024). A company's ability to adopt AI influences its dynamic capabilities, leading to improved firm performance through increased efficiency and productivity (Kumar et al., 2023). AI for companies can help employees manage work simultaneously and obtain data in the production area quickly, thus improving decision-making (Odugbesan et al., 2023; Kumar et al., 2023). The use of AI is growing rapidly to produce low-cost products, therefore achieving competitiveness (Giuggioli & Pellegrini, 2023). Applications in manufacturing companies utilize artificial intelligence by using human-machine interfaces, machine learning, and deep learning (Younis et al., 2022). AI is capable of autonomously analyzing large amounts of data automatically (Nayal et al., 2022). AI streamlines manufacturing processes and can mimic and replace processes performed by humans (Dhamija & Bag, 2020). Company employees can observe and view analyzed data and its options to make informed decisions for both internal and external partners (Tarigan et al., 2020). AI can perform tasks routinely performed by company employees quickly and precisely (Paesano, 2023). AI can also rapidly and accurately anticipate bottlenecks and production process constraints, enabling rescheduling (Mota et al., 2025). Companies utilizing AI can detect malfunctioning equipment or unexpected events (Younis et al., 2022). Companies utilize AI to collect, analyze, and interpret data, enabling informed decision-making during process audits and controls (Wang et al., 2024).

The advantage of AI in manufacturing implementation is integrated into a company's internal processes to control process quality and is aligned with the supply chain flow (Helo & Hao, 2022; Siagian et al., 2022). Supply chain integration in a company includes internal integration, supplier integration, and customer integration (Sègbotangni et al., 2025). The integration of processes within the company's product quality with that of its supplier partners and customers is referred to as quality supply chain integration (Tarigan et al., 2020). Companies must involve external partners in maintaining product quality to respond quickly to internal processes and customer needs, a practice known as supply chain responsiveness (Siagian et al., 2022; Asamoah et al., 2021; Nenavani & Jain, 2022). Total quality management, with a focus on product quality, influences external integration by enhancing strategic supplier relationships and purchasing management (Sharma & Modgil, 2020). Company management can optimize internal processes and the roles of external partners by leveraging AI to enhance operational performance (Helo & Hao, 2022; Baryannis et al., 2019). AI has become a major concern in the development of industrial technology, especially in the manufacturing sector. (Wamba-Taguimdje et al., 2020; Abadie et al., 2023; Odugbesan et al., 2023) Several previous studies have demonstrated that the application of AI can facilitate the development of intelligent manufacturing, expedite decision-making, lower production costs, and enhance company quality and productivity. (Wamba-Taguimdje et al., 2020; Leoni et al., 2022; Chen et al., 2022). AI enables more efficient business processes through the automation of routine and complex tasks, including equipment monitoring, raw material selection, and real-time quality control (Paesano, 2023; Abadie et al., 2023; Younis et al., 2022). Several studies also emphasize the role of AI in supporting digital transformation through the application of machine learning, human-machine interfaces, and deep learning that can integrate various production systems within a company (Kaplan & Haenlein, 2019; Younis et al., 2022). AI enables companies to track inventory in the warehouse, thereby enabling the warehouse system to be automatically controlled (Mukherjee et al., 2024). The company's internal operating process system considers changes in product volume, product variance, and product quality in response to changing demand and adapts to suppliers to ensure smooth internal reconfiguration (Asamoah et al., 2021). AI can be utilized by companies that are strong in implementing technology, enabling automation functions for self-control, self-feedback, and self-decision in carrying out assigned tasks (Chen et al., 2022). Quality management, which is established by the company as a robust system and supported by existing regulations, can lead to increased green innovation in strengthening technology (Li et al., 2018). The company's ability to produce quality products is a result of strong collaboration with suppliers, who automatically provide the required product characteristics (Goswami et al., 2024). Employee knowledge in understanding the customer's process and perspective is crucial in producing quality products. The quality of the products made by the company is an internal integration of quality management principles, complemented by external integration across the organization, to establish product quality standards (Acquah et al., 2023b).

AI in Italian manufacturing companies does not directly impact supply chain resilience; instead, it does so through improvements in knowledge management processes, including knowledge acquisition, creation, and generation, as well as knowledge use and application (Leoni et al., 2022). The ability of employees in companies to adopt AI, considering the operational characteristics of production, can lead to the development of adequate best practices through partial or complete implementation. AI in companies can impact innovative work behavior (Odugbesan et al., 2023). An artificially intelligent adaptive supply chain consists of internal integration and external collaboration (Wang & Zhang, 2025). Supplier and customer integration can significantly impact a company's competitiveness by enabling the production of high-quality products that provide value to customers (Siagian et al., 2022). Information quality within a company is determined by the integration of internal and external supply chains, which impacts firm performance (Pirmanta et al., 2021). Supply chain responsiveness within a company is determined by the technology used in integrated internal processes and external

integration, thereby influencing the company's flexibility, which in turn improves customer service levels (Chunsheng et al., 2020). A company's ability to quickly respond to changes in customer preferences and market needs can lead to increased competitiveness through enhanced responsiveness (Munir et al., 2020). Companies can configure internal integration quality by configuring the operating system to be able to respond to external integration quality (demand management and building relationships with suppliers), which has an impact on improving operational performance with shorter delivery times (Acquah et al., 2023a). Companies can engage with supply chain partners to manage internal and external integration, thereby achieving a steady stream of services and products at low prices and providing optimal value to customers (Huo et al., 2019). Supply chain responsiveness is crucial for companies to accommodate changes occurring in the downstream supply chain, particularly in response to customer needs, thereby enabling sustainable growth for the organization (Nenavani & Jain, 2022).

The novelty of this research lies in the development of a conceptual model that empirically tests the direct and indirect effects of AI implementation on a company's operational performance, mediated by quality supply chain integration and supply chain responsiveness. This research not only adds an external dimension to the evaluation of AI benefits but also unifies the integrative relationship between technology, supply chain processes, and performance outcomes. Based on the explanation above, four broad research objectives can be defined: (1) an artificial intelligence implementation project improves supply chain quality integration and supply chain responsiveness. (2) to determine the magnitude of the effect of quality internal integration on quality external integration and supply chain responsiveness. (3) to determine the effect of quality external integration on supply chain responsiveness. (4) to determine the effect of quality internal integration and supply chain responsiveness on operational performance.

2. Literature Review

2.1. Artificial Intelligence Implementation

AI is a computer program system designed to replace humans by possessing nearly the same level of intelligence in completing tasks effectively (Younis et al., 2022; Dhamija & Bag, 2020). A implementing project of AI in companies can increase productivity and develop new processes, thereby improving company performance (Wamba-Taguimdje et al., 2020). AI enables companies to estimate market segments and make more accurate business decisions (Mukherjee et al., 2024). AI can automatically collect large amounts of data on a single food and analyze it independently (Nayal et al., 2022; Serrano-Torres et al., 2025). AI can generate functions to automate the operation and logistics of information systems (Helo & Hao, 2022). The use of generative AI technology in manufacturing companies aims to streamline operations and business activities, thereby improving performance (Al-khatib et al., 2024). AI's ability in companies to perform tasks independently and autonomously determines the appropriate process (Chen et al., 2022). This condition enables company management to create frameworks that allow humans and machines to work simultaneously to produce informed decisions (Kaplan & Haenlein, 2019). The project implementation of AI in companies tends to vary according to the need to replace workers' tasks in completing one or more processes in the upstream and downstream supply chain (Younis et al., 2022). AI is important for companies because it has been able to replace human capabilities in carrying out processes and solving complex problems using computers (Leoni et al., 2022). AI enables companies to transform rapidly through customization, efficiency, and convenience (Kim & Kim, 2025). Artificial intelligence can identify, assess, and respond to risks that arise in the supply chain (Baryannis et al., 2019). The application of AI in companies can lead to increased productivity and more accurate decision-making, ultimately impacting humans, particularly in terms of joblessness and wealth inequality (Giuggioli & Pellegrini, 2023; Kumar et al., 2023). Leoni et al. (2022) stated that AI adoption in manufacturing companies in Italy was determined by measuring technology-based AI, including machine learning, neural networks, deep learning, computer vision, natural language processing, cognitive computing, predictive analytics, robotic process automation, and semantic search. The primary reason family businesses adopt AI is to increase innovation, which necessitates planning for adoption, identifying AI needs for company operations, and determining the optimal time to implement it (Upadhyay et al., 2023). Artificial intelligence implementation, as determined by Mukherjee et al. (2024), involves several key factors, including the company having the necessary infrastructure and workforce to operate AI, the ability to forecast and predict environmental behavior, the capacity to develop self-learning and prediction models, and the use of AI outcomes to inform SC decision-making collaboratively.

2.2. Quality Internal Integration

Internal quality integration within a company is a comprehensive activity undertaken by the company to produce products that meet customer criteria (Pirmanta et al., 2021). The company strives to involve all existing components in making and achieving predetermined goals (Phan et al., 2019). Internal quality integration encompasses policies and procedures that ensure every process in producing a product or service maintains its quality (Huo et al., 2019). The company ensures that the quality of the resulting product meets the established specifications (Goswami et al., 2024). Internal quality integration within a company can foster strong coordination and collaboration among departments (Acquah et al., 2023b). This condition empowers the company to eliminate communication barriers between departmental functions and produce continuous improvement (Dhaigude et al., 2021). Internal quality integration is determined by the responsiveness of the operational system in delivering quality products and processes that can respond to changing demands (Asamoah et al., 2021). Improved internal quality integration will allow the company to quickly resolve customer issues, ensuring effective interdepartmental

coordination and expedited decision-making. Expected productivity and production capacity can be met, and the company's ability to fulfill customer orders is enhanced. The quality integration process within a company involves all departments within the company's internal supply chain. This includes coordinating with suppliers for raw material procurement, order management, and arranging product delivery to customers (Li et al., 2018). Internal coordination is essential for efficient and effective production, enhancing the company's competitiveness. Internal quality integration enables the company to meet customer needs. The company can plan raw material procurement precisely according to its needs, resulting in increased efficiency in producing high-quality products (Asamoah et al., 2021). This ensures that all departments within the company are well-integrated and coordinated, synchronizing with changes in external partners.

2.3. Quality External Integration

External quality integration is a practice undertaken by companies that involves external partners (suppliers and customers) in maintaining the quality of the company's products. Companies involve external partners in maintaining quality management results to meet customer requirements (Siagian et al., 2022). Companies can establish adequate communication with customers about expected product needs (Pirmanta et al., 2021). Companies can formulate customer problems in a way that allows them to be understood internally and easily communicated to suppliers (Goswami et al., 2024). A company's ability to build collaboration with external partners has a significant impact on increased flexibility. Companies can identify problems that occur with customers to coordinate with suppliers regarding the quality of the resulting product (Phan et al., 2019). This condition affects the company's ability to anticipate defects and rework them early to meet customer orders. External quality integration enables companies to produce products with competitive advantages (Li et al., 2018). Companies that can maintain good external quality integration will be able to increase customer trust (Acquah et al., 2023b). Companies can establish long-term relationships with external partners that are robust and enduring. A company's ability to maintain product quality by involving external partners can reduce the risk of loss by minimizing non-conforming products and responding promptly to changes in demand (Asamoah et al., 2021). Companies can eliminate risks, such as customer complaints and product returns. Products that meet customer specifications will increase customer satisfaction. Established external quality integration can ensure the quality of the product produced, thereby avoiding potential risks. Established external quality integration can support regulatory policies set by the government. Companies can build a competitive advantage and increase customer loyalty. External quality integration can involve components in the supply chain to produce products that meet customer orders with adequate innovation (Huo et al., 2019). Companies involve suppliers in making raw materials and ensuring timely delivery according to company orders. Companies build supplier integration by establishing strategic supplier partnerships, engaging in joint problem-solving and information sharing (Nenavani & Jain, 2022). The company's ability to engage all internal components to produce products according to orders, while building strong communication with customers, is a form of external integration.

2.4. Supply Chain Responsiveness

Supply chain responsiveness is crucial for manufacturing companies, enabling them to provide a significant response to the needs of external partners. Companies strive to adapt their internal conditions in response to external changes (Acquah et al., 2023a). Companies can respond quickly to market changes by increasing internal flexibility. This response may include adjustments to the company's process schedule and, potentially, its policies. Customer changes, such as ordering from different suppliers, can be quickly accommodated to meet material variations (Frederico et al., 2021). The market requires manufacturing companies to make rapid changes in response. A company's ability to quickly respond to changes in external partners can increase its competitiveness (Nenavani & Jain, 2022). Companies can respond to changes in product quantities to meet changing customer demand (Nenavani & Jain, 2022). The company promptly communicates its response to these changes to suppliers. A company's responsiveness to external partners can significantly increase efficiency and effectiveness, as supplier partners fully understand changes occurring internally. Coordination within the company, particularly between relevant departments, allows for a rapid response. Established internal integration can enhance the company's responsiveness to changes in customer relationships. Supply chain responsiveness can be a key factor for a company when internal and external supply chain integration is strong. The company quickly recognizes external changes, and the system can promptly adapt accordingly. An adequate system within the company can quickly respond to external changes, restoring normal operations (Munir et al., 2020). The system established within the company will foster a strong culture for anticipating changes in the supply chain flow, ensuring its stability. This provides a robust operational system that responds quickly to changes in demand and communicates soon with the external supplier network (Asamoah et al., 2021). Companies can build a flexible and adaptable supply chain, demonstrating supply chain responsiveness.

2.5. Operational Performance

A company's operational performance focuses on productivity, efficiency, and effectiveness in increasing competitiveness (Kumar et al., 2023). Companies strive to increase productivity, reduce costs, and produce robust products (Nenavani & Jain, 2022). Companies strive to obtain quality raw materials at affordable costs. Companies strive to make products on tight schedules to ensure timely delivery to customers. Customer satisfaction is crucial for companies in increasing competitiveness. Companies consistently strive to maintain customer satisfaction in order to enhance customer loyalty, which in turn leads to

repeat orders and timely payments (Wungkana et al., 2021). Operational performance in a company is an achievement in the company's operational chain, from the upstream to the downstream supply chain (Phan et al., 2019). Companies strive to maximize output with their available resources. Operational performance, as defined by Nenavani & Jain (2022), refers to the ability to consistently produce products with low defects, meet customer needs for high reliability and durability, and deliver quality products that compete with those of its competitors (Nenavani & Jain, 2022). Firm performance in manufacturing companies is defined by operational performance, including product quality, delivery flexibility, order fulfillment, and customer satisfaction (Pirmanta et al., 2021). Acquah et al. (2023b) define operational performance in terms of key items, including product quality, reliability, and timely delivery. Operational performance in manufacturing companies, according to Sharma & Modgil (2020), is quality, cost, delivery, innovation, defects, inventory, and capacity utilization.

2.6. Relationship between Research Concepts

2.6.1. The relationship between the artificial intelligence implementation project and quality internal integration, quality external integration, and supply chain responsiveness

Utilizing AI to access company statistical data and develop predictive models has a positive impact on making internal processes more flexible and enhancing response times to external partners (Mukherjee et al., 2024). Adopting AI in the dairy supply chain, through data collection, provides real-time data essential for estimating internal and external collaboration needs (Serrano-Torres et al., 2025). AI is an innovative technology in the agricultural sector that can enhance product quality by utilizing machine learning and software robots, thereby reducing food waste (Nayal et al., 2022). A company's ability to create automated operational systems that replace workers can impact process improvements by using internal sensors capable of measuring and responding quickly (Wamba-Taguimdje et al., 2020). AI in the manufacturing industry can run independent processes to perform self-control and self-decision, thereby producing high-quality processes (Chen et al., 2022). AI in industry can assist users in making accurate decisions in business areas, effectively improving process and product quality (Giuggioli & Pellegrini, 2023). Artificial intelligence in renewable energy companies in China, which encompasses two dimensions: internal integration and external integration, has a positive impact on increasing innovative capability within the company and enhancing collaboration capability with external partners (Wang & Zhang, 2025). AI adoption in manufacturing companies relies heavily on the ability of knowledge management processes to adapt to operational needs in daily tasks and solve new problems (Leoni et al., 2022). The use of generative AI in Jordanian manufacturing firms with supply chain activities can be leveraged by all departments to support demand and supply planning, resulting in higher-quality products than competitors (Al-Khatib et al., 2024). The quality of AI recommendations, which generates AI information and system quality, can impact AI service satisfaction by moderating the effects of standardization and customization on sustainable user adoption (Kim & Kim, 2025). The implementation of AI in companies' supplier roles can impact the delivery of customer service (Wang et al., 2024). Manufacturing companies often face challenges in maintaining operational consistency in their production processes and products, which enables them to respond quickly to customer needs (Basana et al., 2025). The company's AI capability in predicting environmental behavior enables companies to enhance supply chain collaboration by forming partnerships with key stakeholders to develop strategic responses before disruptions occur (Mukherjee et al., 2024). AI in companies can assist in rapid decision-making, enabling adaptation and appropriate responses to mitigate potential risks (Baryannis et al., 2019). Quality control in companies maintains quality levels with process capabilities to meet quality product characteristics, integrated with automated optical and visual inspections utilizing artificial neural networks (Mota et al., 2025).

H₁: *The effect of the artificial intelligence implementation project on the quality of internal integration.*

H₂: *The effect of the artificial intelligence implementation project on quality external integration.*

H₃: *The effect of the artificial intelligence implementation project on supply chain responsiveness.*

2.6.2. The relationship between quality internal integration and quality external integration

A company's ability to eliminate internal barriers to integration between departments can significantly impact external integration (Dhaigude et al., 2021). Internal quality integration, determined by the company's operational system in configuring demand requirements and directly communicating with suppliers, is a form of external quality integration that provides quality material requirements, enabling rapid responsiveness to shorten the delivery cycle (Acquah et al., 2023a). Optimized product quality is produced by companies with specific characteristics, tailored to meet customer needs and leverage supplier capabilities, as a form of external integration (Goswami et al., 2024). Integration between departments in providing quality products requires collaboration with external partners (Acquah et al., 2023b). Internal quality management, led by top management, encompasses quality data reporting, quality assurance, and continuous improvement, which can also be applied in external quality management, including upstream and downstream quality management (Phan et al., 2019). A company's ability to maintain product quality by conforming to product specifications and ensuring product quality at each stage of manufacturing can foster strategic supplier partnerships (Sharma & Modgil, 2020). A well-functioning plant, along with the ability to resolve internal problems and conflicts, can impact external integration by fostering cooperative relationships with suppliers and customers (Huo et al., 2019).

H₄: *The effect of quality internal integration on quality external integration.*

2.6.3. *The relationship between internal quality and external integration with supply chain responsiveness*

Companies can maintain internal and external integration to build a resilient supply chain by minimizing the impact of supply chain disruptions and business sustainability through increased responsiveness (Chunsheng et al., 2020). Supply chain responsiveness encompasses two dimensions: the ability of the internal operating system to adapt and configure company assets to meet customer demand and network supplier demand, thereby fulfilling company needs (Acquah et al., 2023a). Supply chain integration enhances supply chain transparency by providing a clear picture of the raw materials and components used to fulfill customer orders (Sègbotangni et al., 2025). The integration formed within a company with external supplier partners to build strategic supplier partnerships and customer relationships has a positive impact on increasing supply chain responsiveness (Nenavani & Jain, 2022). Process control in internal quality management and supplier involvement in quality cannot impact delivery performance in supply chain responsiveness (Phan et al., 2019). Supply chain quality integration, encompassing both internal quality integration and external quality integration, has a positive impact on increasing flexibility, adaptability, and the ability to respond quickly to customer requirements (Huo et al., 2019). The strategic sourcing process established by the company to obtain materials with characteristics that meet production process needs, as a form of quality external integration, has an impact on supply chain responsiveness in anticipating changes in demand (Frederico et al., 2021).

H5: *The effect of quality internal integration on supply chain responsiveness.*

H6: *The effect of quality external integration on supply chain responsiveness.*

2.6.4. *The relationship between supply chain responsiveness and operational performance*

Strong supply chain responsiveness, which enhances a company's ability to fulfill non-standard orders and meet special customer requests, can impact supply chain performance by increasing customer satisfaction with the company's product quality (Munir et al., 2020). Supply chain responsiveness, as demonstrated by a company's ability to handle non-standard customer requests and special customer specifications, impacts operational performance by increasing product quality consistency with low defects and producing products that can compete based on quality (Nenavani & Jain, 2022). Companies respond to changes in the external environment by using digital technology to improve operational capability, firm performance, and customer satisfaction (Marjerison et al., 2025).

H7: *The effect of supply chain responsiveness on operational performance.*

2.6.5. *The relationship between quality internal integration and quality external integration with operational performance*

Supply chain integration, encompassing both internal and external quality integration within a manufacturing company operating in the Indian Chamber of Commerce, has significantly enhanced supply chain performance (Dhaigude et al., 2021). Internal quality integration with the production function works interactively with each other, and strong collaboration between departments in problem-solving has a significant impact on operational performance (Huo et al., 2019). Supplier and customer integration in manufacturing companies can enhance competitiveness by producing products of high quality and volume in response to customer demand (Siagian et al., 2022). External quality integration, established in companies with customer relationship management and strategic supplier partnerships, has significantly improved operational performance (Nenavani & Jain, 2022). Supply chain integration in manufacturing companies impacts firm performance by increasing product quality (Pirmanta et al., 2021). Internal quality integration involves all departments within the company producing quality products and ensuring all process steps are carried out according to standards. This will undoubtedly impact operational performance by creating on-time goods delivery and improving product quality (Sharma & Modgil, 2020). Supplier quality integration and customer quality integration, as external quality integration, impact operational performance by improving product quality, delivery, cost of quality, and flexibility (Huo et al., 2019).

H8: *The effect of quality internal integration on operational performance.*

H9: *The effect of quality external integration on operational performance.*

2.6.6. *The relationship between the artificial intelligence implementation project and operational performance with the mediating variables of quality supply chain integration and responsiveness*

The implementation of AI in companies can enhance integrated systems for quality control and the development of new processes, enabling rapid responses to customers and ultimately improving company performance (Wamba-Taguimdje et al., 2020). Adopting AI in the supply chain to coordinate and optimize activities from raw material procurement to final consumer delivery is crucial for improving efficiency and productivity (Serrano-Torres et al., 2025). The resulting supply chain integration enables companies to meet customer demand by enhancing product quality (Pirmanta et al., 2021). Adoption of AI to obtain data quickly and analyze it automatically to help companies with daily tasks and decision making (Mukherjee et al., 2024; Serrano-Torres et al., 2025), can help in process control (Leoni et al., 2022; Chen et al., 2022; Giuggioli & Pellegrini, 2023) and strengthen collaboration with external partners to maintain product quality (Acquah et al., 2023a; Al-khatib et al.,

2024; Mota et al., 2025) to provide appropriate responses to supply chain flows to improve operational performance (Goswami et al., 2024; Basana et al., 2025; Nenavani & Jain, 2022; Huo et al., 2019; Siagian et al., 2022).

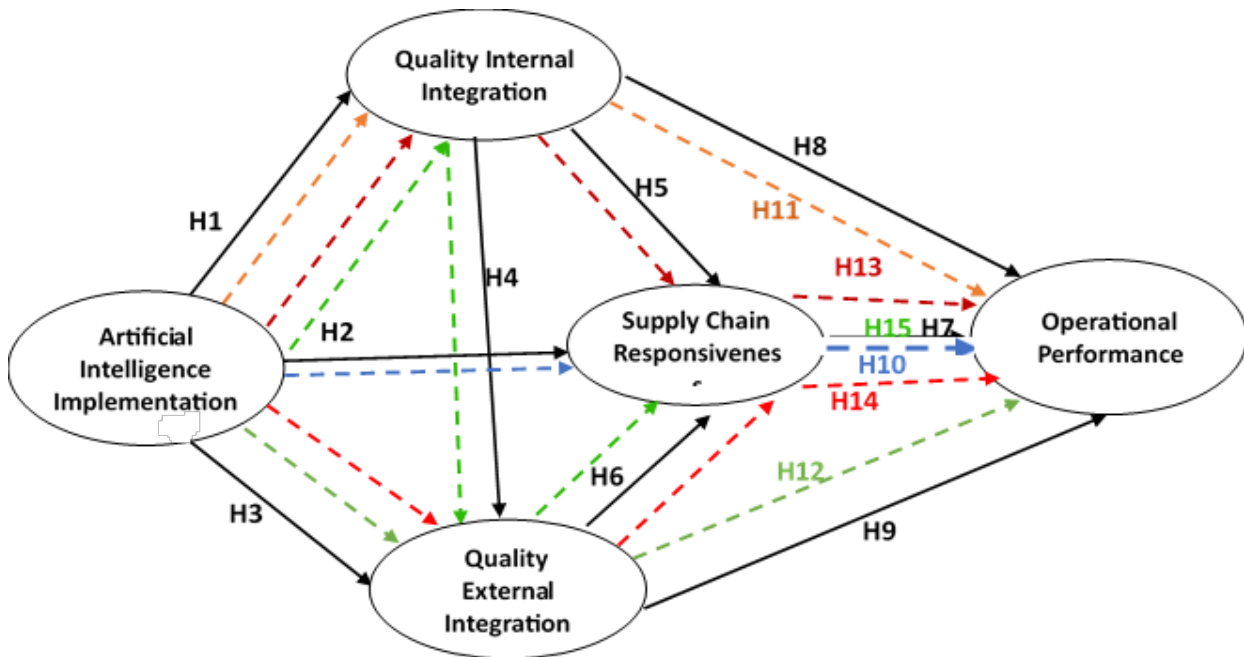


Fig. 1. Research Concept Framework

Based on Fig. 1, the hypotheses can be indirectly determined, namely H₁₀ to H₁₅, with the following statements:

H₁₀: The effect of the artificial intelligence implementation project on operational performance through supply chain responsiveness.

H₁₁: The effect of the artificial intelligence implementation project on operational performance through quality internal integration.

H₁₂: The effect of the artificial intelligence implementation project on operational performance through quality external integration.

H₁₃: The effect of the artificial intelligence implementation project on operational performance through quality internal integration and supply chain responsiveness.

H₁₄: The effect of the artificial intelligence implementation project on operational performance through quality external integration and supply chain responsiveness.

H₁₅: The effect of the artificial intelligence implementation project on operational performance through quality internal integration, quality external integration, and supply chain responsiveness.

3. Research Method

This descriptive quantitative study aims to analyze the synergy between artificial intelligence, supply chain quality, and integration for superior operational performance in the Indonesian manufacturing industry. The study employed a quantitative approach, with interviews and questionnaires as the primary data collection methods. The study population consisted of manufacturing companies in Indonesia, particularly in Java and Bali. The sample companies were manufacturing companies that had implemented system automation, with processes partially or entirely utilizing artificial intelligence. The company's manufacturing process typically utilizes circuit boards for quality control and error detection. Another method involves the use of automation machines to design products tailored to the company's needs. Furthermore, several companies have implemented artificial intelligence in predictive maintenance, utilizing it to monitor and predict equipment failures, minimizing downtime, and optimize maintenance schedules. Data collection was carried out by distributing questionnaires. The project of artificial intelligence implementation (AII) variable is a machine capability that can imitate human intelligence in completing work according to company needs with measurement items the company has machine equipment that has been controlled by a computer (AII1), there is a visible production process for the company (AII2), the company's inventory system has been controlled by a computer system (AII3), the company's staff can operate the computer system (AII4) and the computer system can assist decision making (AII5). The second variable is determined by the quality of internal integration as a process activity within the company, which involves meeting customer demand specifications. Measurement items on quality internal integration by adopting Huo et al. (2019) and Basana et al. (2025) are the company's ability to produce product quality according to criteria (QII1), the company's ability to produce standard processes (QII2), the company's ability to produce reliable products (QII3), the company's ability to produce durable products (QII4), and the company's ability to produce highly competitive products (QII5). The Quality External Integration (QEI) variable refers to activities involving

external partners in the production of quality processes, products, and services. Measurement items The measurement items are determined by adopting Huo et al. (2019) and Basana et al. (2025) for quality external integration are external partners assisting in resolving quality issues (QEI1), raw material quality control has been running well with partners (QEI2), finished product quality control meets quality criteria (QEI3), partner commitment in producing quality products (QEI4), actively involving external partners in maintaining quality (QEI5) and customers providing clear information on quality criteria (QEI6).

Supply chain responsiveness (SCR) refers to a company's ability to adapt to changes in its business environment. The measurement items used for supply chain responsiveness, adapted from research by Munir et al. (2020) and Nenavani & Jain (2022), are the company's ability to meet special customer requests (SCR1), the company's ability to introduce products quickly (SCR2), the company's ability to produce product variants (SCR3), the company's ability to produce product quantities (SCR4), and the company's ability to adapt to non-standard demand changes (SCR5). Conditions created within a company can impact operational performance (OP). The measurement items used for operational performance, adapted from research by Nenavani & Jain (2022), are the accuracy of product delivery to customers (OP1), an increase in the number of customer requests (OP2), increased customer satisfaction with the products produced (OP3), the company's ability to produce affordable product prices (OP4), and the company's ability to reduce product costs (OP5). The questionnaire was designed using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). Data processing was carried out using PLS (partial least squares).

Data collection on manufacturing companies in Indonesia that have utilized artificial intelligence in their production processes, with a focus on the quality of the processes and products produced by these companies. The manufacturing industry in Indonesia in the use of AI includes the use of CNC (Computer Numerical Control) machines, robotics arms, AI-based visual inspection, automated packaging, manufacturing execution systems, and sensor systems working at high temperatures and vibrations. Data collection on manufacturing companies using Google Forms and involving 9 data collection officers in searching for manufacturing companies that have adopted AI. Data collection has resulted in a total of 109 manufacturing companies in Indonesia, with a focus on Java and Bali. The respondent profile shown in manufacturing companies is obtained in Table 1.

Table 1
Respondent Profile

| Characteristic | Description | Qty | Percentage |
|--------------------------------------|----------------------------------|-----|------------|
| Gender | Male | 68 | 62% |
| | Female | 41 | 38% |
| Respondent department | Operational & Production | 59 | 54% |
| | Engineering | 14 | 13% |
| | Warehouse | 11 | 10% |
| | Finishing | 7 | 6% |
| | Quality Assurance/Control | 18 | 17% |
| Respondent's position in the company | General Manager/Director | 7 | 6% |
| | Manager | 62 | 57% |
| | Supervisor | 21 | 19% |
| | Staff | 19 | 17% |
| Work experience at the company | More than 10 years | 56 | 51% |
| | 5 -10 years | 33 | 30% |
| | 3 - 5 years | 12 | 11% |
| | 1- 3 Years | 8 | 7% |
| AI Adoption in the Company | CNC (Computer Numerical Control) | 65 | 30% |
| | Robotics arms | 4 | 2% |
| | AI-based visual inspection | 7 | 3% |
| | Automatic packaging | 32 | 15% |
| | Manufacturing execution system | 34 | 15% |
| | Sensor system | 78 | 35% |

The respondent profile obtained was male (68 people). Respondent characteristics based on the work department were the largest in operations & production (59 people). The majority of respondents (62 people, 57%) had a position, and 56 (51%) had more than 10 years of work experience. Respondents have adequate knowledge, experience, and work skills. The use of AI in manufacturing companies has been widely implemented, but its implementation varies across different process functions. While some companies have adopted AI to achieve high productivity and efficiency, others have utilized it in smaller capacities.

4. Results and Discussion

The results of data processing using PLS (Partial Least Squares) to obtain the goodness of fit criteria for the outer model are shown in Table 2.

Table 2
The Goodness of Fit Outer Model

| Item | Mean | Factor Loading | Composite reliability | Cronbach alpha | AVE |
|---|--------|----------------|-----------------------|----------------|-------|
| Artificial Intelligence Implementation | 4.3593 | | 0.929 | 0.904 | 0.725 |
| AII1 | 4.3889 | 0.752 | | | |
| AII2 | 4.4815 | 0.860 | | | |
| AII3 | 4.4259 | 0.892 | | | |
| AII4 | 4.2870 | 0.874 | | | |
| AII5 | 4.2130 | 0.873 | | | |
| Quality Internal Integration | 4.2944 | | 0.904 | 0.896 | 0.659 |
| QII1 | 4.0556 | 0.783 | | | |
| QII2 | 4.2130 | 0.760 | | | |
| QII3 | 4.5648 | 0.834 | | | |
| QII4 | 4.4167 | 0.798 | | | |
| QII5 | 4.2222 | 0.846 | | | |
| Quality External Integration | 4.0725 | | 0.920 | 0.896 | 0.659 |
| QE11 | 4.1759 | 0.815 | | | |
| QE12 | 4.0556 | 0.794 | | | |
| QE13 | 3.9074 | 0.789 | | | |
| QE14 | 3.7500 | 0.778 | | | |
| QE15 | 4.2778 | 0.876 | | | |
| QE16 | 4.2685 | 0.814 | | | |
| Supply Chain Responsiveness | 4.2278 | | 0.914 | 0.868 | 0.654 |
| SCR1 | 4.3148 | 0.870 | | | |
| SCR2 | 4.3056 | 0.896 | | | |
| SCR3 | 4.3241 | 0.895 | | | |
| SCR4 | 3.9815 | 0.734 | | | |
| SCR5 | 4.2130 | 0.716 | | | |
| Operational Performance | 4.2185 | | 0.876 | 0.820 | 0.682 |
| OP1 | 4.1944 | 0.792 | | | |
| OP2 | 4.3056 | 0.778 | | | |
| OP3 | 4.1667 | 0.890 | | | |
| OP4 | 4.1019 | 0.812 | | | |
| OP5 | 4.3241 | 0.524 | | | |

The average value for each variable shows that AI implementation has helped the company perform well, with an average value of 4.3593, indicating that AI adoption can produce high-quality work. The company utilizes numerous CNC machines and automated packaging systems in its operational areas, thereby enhancing productivity and efficiency. The average value for internal quality integration is 4.2944, indicating that all departments within the company have maintained the quality of processes and products by the established specifications, which are highly competitive. External quality integration is achieved with an average value of 4.0725, with the highest value being achieved through actively involving external partners in maintaining quality, at 4.2778. External quality integration has been running smoothly, along with the involvement of external partners in the company's program to maintain product quality. The company's ability to build supply chain responsiveness, with an average value of 4.2278, indicates that it has effectively produced product variances and controlled the quality of raw materials with its partners, thereby meeting customer needs. The resulting operational performance is 4.2185, indicating that the company has successfully met the increasing number of customer requests and can reduce product costs. Based on the calculation and bootstrapping results, it shows that the indicator weight and loading factor have met the requirements of ≥ 0.500 (all measurement items meet the validity test). Testing on the measurement indicator block with an AVE value of ≥ 0.500 , composite reliability of ≥ 0.700 , and Cronbach's alpha of ≥ 0.700 has met the requirements. The next stage is to test the inner model in Fig. 2 and Table 3.

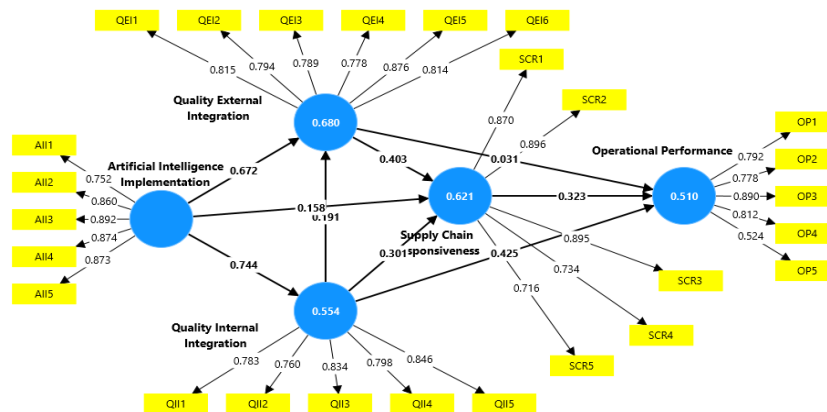


Fig. 2. Path Analysis of Research Full Structural Model

Table 3
Hypothesis of Research and Path Coefficient

| Hypothesis of Research | Path Coefficient | T-statistics | P-values |
|--|------------------|--------------|----------|
| Artificial Intelligence Implementation → Quality Internal Integration (H1) | 0.744 | 11.406 | 0.000 |
| Artificial Intelligence Implementation → Supply Chain Responsiveness (H2) | 0.158 | 1.174 | 0.240 |
| Artificial Intelligence Implementation → Quality External Integration (H3) | 0.672 | 10.068 | 0.000 |
| Quality Internal Integration → Quality External Integration (H4) | 0.191 | 2.206 | 0.027 |
| Quality Internal Integration → Supply Chain Responsiveness (H5) | 0.301 | 2.652 | 0.008 |
| Quality External Integration → Supply Chain Responsiveness (H6) | 0.403 | 3.578 | 0.000 |
| Quality Internal Integration → Operational Performance (H7) | 0.425 | 3.961 | 0.000 |
| Quality External Integration → Operational Performance (H8) | 0.031 | 0.352 | 0.725 |
| Supply Chain Responsiveness → Operational Performance (H9) | 0.323 | 2.248 | 0.025 |
| Artificial Intelligence Implementation → Supply Chain Responsiveness → Operational Performance | 0.051 | 1.061 | 0.289 |
| Artificial Intelligence Implementation → Quality Internal Integration → Operational Performance (H11) | 0.371 | 3.931 | 0.000 |
| Artificial Intelligence Implementation → Quality External Integration → Operational Performance (H12) | 0.021 | 0.348 | 0.728 |
| Artificial Intelligence Implementation → Quality Internal Integration → Supply Chain Responsiveness → Operational Performance (H13) | 0.072 | 1.486 | 0.137 |
| Artificial Intelligence Implementation → Quality External Integration → Supply Chain Responsiveness → Operational Performance (H14) | 0.087 | 1.715 | 0.086 |
| Artificial Intelligence Implementation → Quality Internal Integration → Quality External Integration → Supply Chain Responsiveness → Operational Performance (H15) | 0.019 | 1.241 | 0.215 |

Based on the results of Table 3, the research hypothesis and the path coefficient, the results of testing the research hypothesis were obtained. The first research hypothesis was that the implementation of artificial intelligence on quality internal integration (H1) yielded a t-statistic value of 11.406 (> 2.364), indicating that the first hypothesis can be accepted with a significance level of 0.01. The implementation of artificial intelligence as a company inventory system has utilized a computer system, and the staff's ability to operate this system has resulted in a 0.744 increase in internal integration quality, leading to rapid coordination between all departments. The results of this study support the findings of previous studies, which indicate that the implementation of artificial intelligence has an impact on internal integration quality (Mukherjee et al., 2024; Nayal et al., 2022; Wamba-Taguimdje et al., 2020; Chen et al., 2022). Testing the second hypothesis, the artificial intelligence implementation on supply chain responsiveness yielded a t-statistic value of 1.174 (< 1.96), indicating that the hypothesis was rejected with a significance level of 0.05. Artificial intelligence implementation, combined with system, computer, and staff expertise, is unable to significantly impact supply chain responsiveness in meeting specific customer demands; however, mediation of internal quality and external quality integration is required. The results of this study support the findings of previous studies, which suggest that the implementation of artificial intelligence has an impact on internal quality integration, with mediation of both internal quality and external quality integration (Baryannis et al., 2019; Mukherjee et al., Wang et al., 2024; Kim & Kim, 2025). This study differs from previous studies that suggest artificial intelligence implementation has a direct effect on supply chain responsiveness (Chen et al., 2022; Giuglioli & Pellegrini, 2023; Wang & Zhang, 2025). The third hypothesis test, specifically the implementation of artificial intelligence in external quality integration, yielded a t-statistic value of 10.068 (> 2.364); therefore, it is concluded that the third hypothesis is accepted with a significance level of 0.01. The implementation of artificial intelligence within the company's inventory system has enhanced the system's impact on supply chain responsiveness, specifically the company's ability to introduce products quickly. The results support research that suggests the effects of artificial intelligence implementation on quality external integration (Wang et al., 2024; Mukherjee et al., 2024; Mota et al., 2025).

As the fourth hypothesis, the t-statistic value obtained was 2.206 (> 1.96), indicating that the fourth hypothesis is acceptable with a significance level of 0.05. The company's ability to produce reliable and highly competitive products, combined with internal integration, has a significant impact on external quality integration. The formation of raw material quality control has been running well with partners. The results of the study support the results of previous studies, which stated that quality internal integration has a significant effect on quality internal integration (Dhaigude et al., 2021; Acquah et al., 2023a; Goswami et al., 2024; Acquah et al., 2023b; Phan et al., 2019; Sharma & Modgil, 2020). Coordination carried out within the company between departments can adequately and effectively improve a strong procurement strategy for providing raw materials with supplier partners, according to the required material characteristics, to meet customer order product specifications. Quality internal integration towards supply chain responsiveness is the fifth hypothesis, obtained with a t-statistic value of 2.652 (> 2.364). Therefore, it can be said that the fifth hypothesis factor is acceptable with a significance level of 0.01. The company's ability to produce quality products according to its internal production criteria, as well as its quality internal integration, significantly increases supply chain responsiveness. The company's ability to produce quality products that meet specific customer demands and generate product variance is crucial. The results of this study support previous research, which stated that quality internal integration significantly influences supply chain responsiveness (Chunsheng et al., 2020; Sègbotangni et al., 2025; Nenavani & Jain, 2022; Phan et al., 2019).

The quality of external integration in supply chain responsiveness, as the sixth hypothesis, yielded a t-statistic value of 3.578 (> 2.364), indicating that the fourth hypothesis can be accepted with a significance level of 0.01. Raw material quality control has been running smoothly with partners, and partner commitment to producing quality products can significantly impact supply chain responsiveness by enhancing the company's agility in introducing products quickly and its ability to adjust to non-standard demand changes. The results of the study align with those of previous studies, which have found that quality external integration has a significant impact on supply chain responsiveness (Sègbotangni et al., 2025; Nenavani & Jain, 2022; Huo et al., 2019; Frederico et al., 2021). The quality internal integration of operational performance, as the seventh hypothesis, obtained a t-statistic value of 3.961 (> 2.364), indicating that the seventh hypothesis is acceptable with a significance level of 0.01. Quality internal integration involves all departments within the company in producing products of high quality according to established criteria, standard processes, and reliable and durable products. This approach has a significant impact on operational performance, as it enables timely product delivery to customers and increases customer satisfaction with the product. The results of the study support those of previous studies, which indicate that quality internal integration has a significant impact on improving operational performance (Munir et al., 2020; Nenavani & Jain, 2022; Marjerison et al., 2025). The quality of external integration on operational performance, as the eighth hypothesis, yielded a t-statistic value of 0.352 (< 1.96), indicating that the hypothesis is rejected. Quality external integration formed in the company with raw material quality control has been running well with partners, but it does not have a direct impact on operational performance; instead, it has a significant effect through supply chain responsiveness, so that the company fulfills customer requests specifically, introduces products quickly, and adjusts to non-standard demand changes. The results of the study support those of previous studies, which suggest that quality external integration improves operational performance through the mediation of supply chain responsiveness (Huo et al., 2019; Siagian et al., 2022; Pirmanta et al., 2021; Sharma & Modgil, 2020). Supply chain responsiveness and operational performance, as hypothesized in hypothesis nine, yielded a t-statistic value of 2.248 (> 1.96), indicating that the hypothesis is accepted. The company's ability to fulfill customer requests specifically, introduce products quickly, provide adequate product variety, and provide the appropriate number of products as a form of supply chain responsiveness has a direct impact on operational performance by increasing the accuracy of product delivery to customers, customer satisfaction with the products produced, and the company's ability to reduce product costs. The research results align with previous studies, which have found that supply chain responsiveness has a positive impact on operational performance (Huo et al., 2019; Sharma & Modgil, 2020; Siagian et al., 2022).

Testing of the indirect hypothesis, namely H10-H15. The implementation of artificial intelligence affects operational performance through supply chain responsiveness, as the tenth hypothesis obtained a t-statistic value of 1.061 (< 1.96), indicating that the hypothesis is rejected. The eleventh hypothesis, which posits that the implementation of artificial intelligence affects operational performance through quality internal integration as an intervening variable, yielded a t-statistic value of 3.931 (> 2.364), indicating that the hypothesis is accepted. Testing of the twelfth hypothesis regarding the implementation of artificial intelligence on operational performance through quality external integration yielded a t-statistic value of 0.348 (< 1.96), indicating that the hypothesis is rejected. Artificial intelligence implementation on operational performance through quality internal integration and supply chain responsiveness as the thirteenth hypothesis obtained a t-statistic value of 1.486 (< 1.96), so it is said that the hypothesis is rejected. The fourteenth hypothesis testing the artificial intelligence implementation on operational performance through quality external integration and supply chain responsiveness yielded a t-statistic value of 1.715 (> 1.65), indicating that the hypothesis is accepted at a significance level of 0.1. Quality internal integration, as an intermediary variable, plays a crucial role in the implementation of artificial intelligence to improve operational performance, thereby enhancing the competitiveness of manufacturing companies in Java and Bali. The ability of management to leverage artificial intelligence to meet the needs of the production process can improve company productivity and efficiency. Artificial intelligence implementation also plays a significant role in involving external partners to actively maintain quality, and customers provide clear information on quality criteria. This condition enables customer demand to be met with product variance, a form of supply chain responsiveness that ultimately impacts operational performance.

This research provides significant practical contributions to the manufacturing sector in Indonesia, particularly for companies currently implementing or planning to implement Artificial Intelligence (AI) technology in their production systems. The research demonstrates that AI implementation directly improves both internal integration and external integration, both of which are essential factors in enhancing productivity, a foundation crucial for achieving superior operational performance. Manufacturing companies can utilize the findings of this study as a reference when selecting relevant AI technology for production and quality control processes, enhancing staff competency in operating AI-based systems, and developing integration strategies for technology with internal and external business processes. The results indicate that external collaboration (quality external integration) must be supported by strong internal integration to have a significant impact on supply chain responsiveness and operational performance. In practice, it is expected that companies will be able to build quality communication with suppliers and customers, apply a quality monitoring system with external partners, and prepare flexible strategic partnership contracts to meet changing market demands. This research contributes theoretically by developing a comprehensive conceptual model that integrates the implementation of artificial intelligence, internal quality integration, external quality integration, supply chain responsiveness, and operational performance. This model examines direct and indirect relationships, as well as the role of mediation, which has not been widely studied holistically in the Indonesian manufacturing context. This research strengthens and expands the literature in the fields of Supply Chain

Management, Total Quality Management (TQM), and information technology by emphasizing the importance of integrating intelligent technology systems with quality management strategies to improve operational competitiveness.

5. Conclusions

This study was conducted to empirically test the effect of Artificial Intelligence (AI) implementation on the operational performance of manufacturing companies in Indonesia, by positioning quality internal integration, quality external integration, and supply chain responsiveness as mediating variables that form a complex and comprehensive relationship path. The results of the hypothesis testing indicate that AI implementation has a positive and significant effect on both internal quality and external quality. The adoption of AI technology can significantly enhance cross-departmental coordination and foster synergy with external partners, such as suppliers and customers. With automated systems and fast and accurate data processing, companies can produce high-quality, standard-compliant processes and products, and build long-term partnerships based on trust and quality collaboration. A company's ability to establish a robust internal quality system directly impacts its capacity to collaborate with external parties in maintaining product quality and responding promptly to changes in market demand. These findings highlight the significance of internal cross-functional synergy in enhancing operational efficiency and overall supply chain agility.

Supply chain responsiveness was also found to have a positive influence on operational performance, which in this study was measured through indicators such as timely product delivery, customer satisfaction, the ability to meet special requests, and production cost efficiency. High supply chain responsiveness enables companies to quickly adjust production to changing demand, introduce new products rapidly, and produce product variations according to customer needs. The direct effect of AI on supply chain responsiveness and operational performance was not significant. The positive impact of AI on operational performance emerged only indirectly, primarily through the mediation of quality internal integration. AI adoption needs to be supported by mature and integrative internal processes for its impact on company performance to be truly realized. AI technology is not a single factor determining operational excellence; rather, it must be part of an integrated managerial and operational system. The impact of AI adoption on company performance is complex and not always immediately visible. However, it requires the support of an organizational structure, a culture of quality, and adequate supply chain integration. Overall, the study findings emphasize that the operational excellence of manufacturing companies depends not only on the adoption of advanced technologies, such as AI, but also significantly on the extent to which the company can integrate internal and external functions within its supply chain system. In the context of manufacturing in Indonesia, this study provides empirical evidence that AI has significant potential to enhance operational performance; however, this achievement is highly influenced by the readiness of the company's internal quality system and its capacity for external collaboration.

Acknowledgments

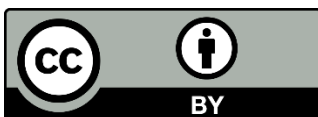
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