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The human-machine interface enables collaborative decision-making and supply chain flexibility to boost operational performance

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A B S T R A C T

Using technology, such as human-machine interfaces, can enhance operational performance processes and increase the flexibility of the supply chain. Human-machine interfaces can produce operational control systems quickly and accurately. The research aims to explore the impact of human-machine interface on operational performance through collaborative decision making and supply chain agility. The sample criteria are the manufacturing companies with over 20 employees in Indonesia. The questionnaires were distributed offline (76 respondents) and online through Google Forms (427 respondents), so 503 questionnaires were valid—data processing using SmartPLS software version 4.0. The study results showed that the human-machine interface technology positively affects collaborative decision-making, supply chain flexibility, and operational performance with coefficients of 0,559, 0,490, and 0,340, respectively. Collaborative decision-making involving customer partners in planning decisions and communicating decisions with external partners influences supply chain flexibility by a coefficient of 0.375 and operational performance by 0.149. Moreover, supply chain flexibility with flexible planning and production processes and flexible labor placement influences operational performance by a coefficient of 0.381. The practical contribution of research enlightens company managers to build integrated systems and automation. It encourages top management and owners to think about investing in machines with high automation in the economy. Besides, these findings enrich the theoretical background in supply chain management and the resource-based view.

1. Introduction

Technological developments in the modern era have impacted various industrial sectors. Technology is now an important part of industrial operations, producing efficient and effective production processes (Rojo et al., 2018). The technology used by the company can be a control system in the production process (Harianto et al., 2024). Industries that use conventional control systems that operate manually and are limited make it difficult for companies to increase productivity and competitiveness, which is increasingly declining. The use of technology can increase efficiency and reduce operational costs. Many industries use technology according to their needs (Wu et al., 2014).

The technology in automatic control systems has been widely applied and adopted (Jeng et al., 2021). The technology replaces conventional control with more modern and integrated technology (Falandays et al., 2021). The main advantage of an automated control system is its ability to improve the efficiency of the production process (Shahab et al., 2023), reduce processing time, and significantly reduce production costs. Technology makes automation a strategic solution in facing increasingly fierce industry competition (Kumar et al., 2018). Implementing an automatic control system also has long-term impacts on companies (Shahab et al., 2023), including increased productivity and production quality (Ansari et al., 2018).

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With automation, companies can make more optimal use of resources and respond to market needs more quickly (Wang et al., 2023a). This transformation not only supports operational efficiency but also opens up innovation opportunities that contribute to the company's competitiveness at the global level (Nagarajan et al., 2013).

Human-machine interface is an interface between humans and machine technology that works collaboratively (Beltramini, 2018; Wu et al., 2022) in a system capable of controlling complex production processes to produce simultaneous activities (Bouyam & Punsawad, 2022). The human-machine interface owned by a manufacturing company can control a process from the control room (Cao et al., 2021). Workers in the company can use monitors to operate a process whose characteristics are known to produce optimal production (Sitompul, 2022). Human-machine interface has a strategic role in integrating data on machines into computer systems (Cao et al., 2021) to be quickly integrated into providing reports and analytics that help in joint decision-making with effective results (Li et al., 2023). The human-machine interface can help management get data in real-time as needed (Singh & Kumar, 2021) to make strategic decisions with partners to improve the company's performance (Haesevoets et al., 2021).

The era of digitalization continues to develop with an impact on HMI and supply chain flexibility, and it is a strategic combination that creates a competitive advantage. HMI can be leveraged with the capabilities of analytics and machine automation in decision-making (Jiang, 2020; Liu et al., 2024). Companies can build resilient and adaptive supply chains by using HMIs adequately and can face global challenges (Kosicki & Thomessen, 2013). The key characteristics of collaborative decision-making are the active involvement of the customer and supplier sides in the supply chain (Wu et al., 2014; Kumar et al., 2018). Companies must always involve partners in solving their problems if they need a large partner role (Siagian et al., 2021). The process of solving problems in the company cannot be solved unilaterally by the company (Cao et al., 2021). The company still involves discussions with various supplier partners and customers (Kumar et al., 2018). Collaboration in decision-making emphasizes the importance of transparent information integration and communication so that each party plays a role according to their respective activeness (Levalle & Nof, 2015). Collaborations formed in companies need to be processed periodically on an ongoing basis (Li et al., 2023). The company's ability to involve partners to set plans and other activities as a common interest can improve the company's operational performance (Rojo et al., 2018). The decision for collaboration that the company sets on an ongoing basis makes the company able to adapt well to market changes (Wu et al., 2014; Basana et al., 2023). The role of collaborative decision-making in supply chain flexibility is to manage the size of inventory levels to anticipate changes (Nematollahi et al., 2017; Ali et al., 2024). Collaborative decision-making is flexible in various aspects of operations and information obtained (Daghar et al., 2021). Companies and suppliers share information in real time (Singh & Kumar, 2021; Mustafa et al., 2023) so that stocks can be adjusted to changes in demand without sacrificing efficiency (Nagarajan et al., 2013). Collaborative decision-making helps cross-functional teams to align decisions related to capacity planning and production scheduling based on dynamic market needs (Lai et al., 2020).

Companies constantly strive quickly to change continuously in uncertain changes but can adapt with high flexibility (Willis et al., 2016). The company's ability to build good cooperation with suppliers and have adequate quality so that it can provide raw materials following the requirements that have been set (Basana et al., 2025). Companies can pay attention and identify and monitor the delivery history of suppliers (Shukor et al., 2021). Supply chain flexibility is the ability of companies to proactively monitor and manage relationships with parties with interdependencies in operations with external partners such as suppliers, manufacturers, and distributors dynamically (Chaudhuri et al., 2018). This relationship must be maintained with close coordination so that companies can respond quickly to market changes and unexpected disruptions (Cao et al., 2021). With supply chain flexibility, companies can build resilience and rapid response, which is key in facing increasingly dynamic market challenges (Tarigan et al., 2024). Flexibility becomes important when every member in the supply chain works synergistically to adapt to the changing business environment (Rojo et al., 2018). This synergy allows companies in the supply chain to respond to market demand more effectively and efficiently (Nagarajan et al., 2013). With high flexibility, companies can adjust their operational strategies and maintain business continuity in unstable market conditions. Ideal supply chain flexibility can dynamically meet customer needs by providing quality products (Chaudhuri et al., 2018; Basana et al., 2025). Flexibility to adapt quickly to changing customer needs so that it can increase competitiveness (Siagian et al., 2021). Speed is an important element in flexibility that includes adaptability and responding quickly to maintain customer satisfaction and company competitiveness (Harianto et al., 2024). Companies can face market challenges by integrating flexibility into supply chain strategies (Tarigan et al., 2024). The ability to respond quickly and flexibly to changes in the business environment provides a competitive advantage (Chaudhuri et al., 2018). Supply chain flexibility allows companies to survive and thrive in markets fraught with external environmental uncertainty (Ali et al., 2024), making it a key element in operational success (Soesetyo et al., 2024).

Human-Machine Interface (HMI) is a strong interaction between workers and machines through interfaces (Sitompul, 2022; Jain et al., 2024) in controlling the continuity of simple and complex processes in improving operational performance (Tarigan, 2018; Ansari et al., 2018). Workers can determine the speed of a process (Xiong et al., 2023) and product quality to achieve customer requirements as a form of performance achievement (Tarigan & Siagian, 2021; Basana et al., 2025). HMI can visualize company data in real-time (Somon et al., 2019) to ensure strong effectiveness and maintain operational performance (Mustafa et al., 2023). HMI enables companies to obtain analysis data quickly and adequately (Morgan et al.,

2021) to produce strategy decisions for top management to increase competitiveness (Liu et al., 2024). Company workers can work easily and safely in operating company equipment (Sitompul, 2022) to maintain worker safety and produce stable operational performance (Tarigan et al., 2023). Collaborative decision-making for companies involves internal and external partners as components of the supply chain strategy to maintain stable company operational performance (Wu et al., 2014; Kumar et al., 2018). Companies can collaborate with partners in making decisions to anticipate market changes (Daghar et al., 2021). The company can adjust quickly to customer order changes to provide customer satisfaction. Companies can also make processes efficient and effective when the planned plan is supported by partners (Nagarajan et al., 2013). Collaborative decision-making is relevant in a business environment with operational challenges requiring a cross-functional and cross-organizational approach that results in operational performance (Nematollahi et al., 2017; Tarigan, 2018). The collaborative decision-making process (Hao et al., 2024) allows alignment between various organizational units, thereby reducing the potential for conflicts or mismatches to maintain operational performance (Cao et al., 2021). Collaborative decision-making impacts company performance by encouraging process and product innovation that suits customer needs (Jain et al., 2023). Collaborative decision-making also strengthens relationships in the supply chain through better communication (Long, 2016; Wang et al., 2023b), so that the production planning process can run well. This condition results in the production process running well due to the availability of the right raw materials (Levalle & Nof, 2015). Collaborative decision-making by involving various supply chain component parties (Kumar et al., 2018), namely suppliers and customers, in the decision-making process to improve supply chain flexibility so that the company's operational performance is maintained effectively and strategically (Lai et al., 2020; Yu et al., 2018). HMI combines collaborative decision-making (Xiong et al., 2023) and supply chain flexibility to make the production process right on target (Zhang et al., 2024). HMI can provide fast data so that it is easy to respond to changes in customer demand, which impacts improving operational performance (Wu et al., 2022). The company's supply chain flexibility can bridge the influence of HMI with operational performance by increasing adaptability.

Based on the above description, this research objectives consist of four major goals: First, obtaining assessing the influence of human-machine interfaces on collaborative decision-making, supply chain flexibility, and operational performance. Second, examines the influence of collaborative decision-making on supply chain flexibility and operational performance. Third, investigate the impact of supply chain flexibility on operational performance. Fourth, addressing the mediating role of collaborative decision-making, and supply chain flexibility on the relationship of the human-machine interface and operational performance. The research findings are expected to contribute to managerial implications on how to improve the operational performance in the manufacturing industry. In addition, the findings will enrich the theoretical background in supply chain management.

2. Literature Review

2.1. Human-machine interface

The human-machine interface (HMI) is an interface between humans and machine technology that allows the two collaboratives in a production system to improve productivity and operational performance simultaneously (Beltramini, 2018). The interface between humans and machines is through a computer displayed on a monitor (Bouyam & Punsawad, 2022). Human interaction with machines through interfaces, known as Human Machine Interface (HMI) has become a critical element in various automated systems (Li et al., 2023; Falandays et al., 2021). HMIs allow users to perform various functions, such as starting or stopping processes, selecting operating modes, and monitoring running system activity (Mustafa et al., 2023). With the existence of HMI, humans can also intervene in the work of machines that previously operated automatically (Shahab et al., 2023), thus providing greater flexibility in operation system (Mourtzis et al., 2023). Workers in the company can observe production results by using the available monitors (Ansari et al., 2018). Operators can control the results of the process by using indicators on the computer monitor (Jeng et al., 2021). Monitors and layers are used to operate a process whose characteristics are known so that it can control process variables (Somon et al., 2019). The parameters shown on the layer can help the operator to find out the real condition of the machine (Mustafa et al., 2023). Humans on machines are responsible for the production process to adjust to operational procedures. The operator's ability to run machine processes and use monitors to produce optimal processes and have an adequate sense of security (Wang et al., 2023a).

In the manufacturing industry, HMI can be shown on a layer computer display that the operator observes the process results at a certain time (Mustafa et al., 2023). Companies can use machine controls visually on layers so enabling them to easily control (Jain et al., 2024). Hence, operators can control all processes in the company by paying attention to the computer monitor layer (Sitompul, 2022). Consequently, companies can maintain product quality and production process speed from the control room and to determine decisions (Jiang, 2020). Company employees can control the process quickly and precisely in real-time (Alsubaie & Aldoukhi, 2024) without the need to go to the machine's operational area to control the process (Singh & Kumar, 2021). Companies, through operators, can control production optimization by paying attention to product characteristics that are adjusted to the working principles of the machine (Mustafa et al., 2023). The use of machines through human-machine interfaces provides an increased level of security (Li et al., 2023). The role of HMIs is not only

limited to controlling machines but also creates a more intuitive relationship between humans and technology (Cao et al., 2021). The technology is designed to simplify operations by providing a user-friendly interface, allowing humans to access data, analyze system conditions, and make decisions more quickly (Jain et al., 2023). In other words, HMIs serve as a bridge that connects the human ability to think critically with machines' precise and efficient performance (Zhang et al., 2024; Liu et al., 2024; Morgan et al., 2021).

Machine interfaces greatly help operators because they get notifications if something goes wrong with the company's machine system (Jain et al., 2024). The human-machine interface in the company has images and graphics that can be adjusted to the company's needs effectively (Xiong et al., 2023). The appearance of a human-machine interface on a machine to control the process (Zhang et al., 2024). Workers on the company's production floor can understand the machine's working characteristics to automatically run adequate programs to maintain the continuity of the process (Falandays et al., 2021). Workers can adjust the machine's condition to the company's real needs so that the process balance can be maintained properly (Jeng et al., 2021). The ability of employees to use human-machine interfaces in production can increase the company's flexibility (Tarigan et al., 2024). Adequate human-machine interface system conditions can help in strong decision-making (Wu et al., 2022). Because the human-machine interface can provide information on process results accurately, in detail, and in a structured manner so that the information becomes complete (Alsubaie & Aldoukhi, 2024). HMI's positive impact is felt in various industrial sectors such as manufacturing, energy, transportation, and other industrial processes. Improving operational efficiency, productivity, and occupational safety (Morgan et al., 2021). HMI has become a tool that supports industrial activities and encourages further technological innovation (Zhang et al., 2024). In a world increasingly dependent on automation (Shahab et al., 2023), the existence of HMIs contributes significantly to ensuring that complex systems remain accessible and controlled by humans efficiently and effectively.

2.2. Collaborative decision-making

Collaborative decision-making is important in improving coordination and integration within the supply chain (Cao et al., 2021). This process involves supply chain partners working together to plan and manage operations in a coordinated manner, aiming to improve efficiency and overall performance (Wu et al., 2014). Activities in collaborative decision-making can involve planning with partners (Wang et al., 2023b). Companies can collectively involve suppliers and customers in solving problems (Kumar et al., 2018). Development of rules and procedures agreed with external partners to create synergy among various parties involved (Daghar et al., 2021). The approach to the supply chain involves the company's partners in collaborative decision-making that covers various strategic aspects such as transportation, freight forwarding, warehousing, insurance, and other value-added services. All decisions taken collaboratively aim to create an integrated process (Nematollahi et al., 2017). Decisions that involve company partners on an ongoing basis can reduce inefficiencies and ensure customer needs are met effectively. A collaborative approach can also prioritize better resource management and faster response to changing market conditions (Hao et al., 2024). The main characteristic of collaborative decision-making is the active involvement of all parties in the supply chain (Lai et al., 2020). This process depends on one internal company party and involves discussions and agreements with various supplier partners and customers. Collaboration in decision-making emphasizes the importance of transparent information and communication integration so that each party has the same understanding of the goals to be achieved (Wang et al., 2023b). Collaboration in decision-making is not limited to a specific period only (Jiang, 2020). Companies must involve external partners if there are still activities or interrelated interests among supply chain partners. Flexibility for all parties to continue to work together when facing challenges and taking advantage of existing opportunities. This ongoing collaboration allows for better adaptation to market dynamics and customer needs. This process also requires careful joint planning so that responsibility for implementing decisions can be shared fairly. With structured planning, the risk of conflict or misunderstanding can be minimized. Collaborative decisions also ensure that each party understands its role and contribution in supporting the success of decisions taken jointly (Daghar et al., 2021). Collaboration is a fundamental difference from teamwork because it is longer and lasts continuously (Nagarajan et al., 2013). In collaboration, the interaction between the parties involved is in-depth and often involves constant discussion (Li et al., 2023). This process also encourages planned knowledge sharing so that decisions are based on a comprehensive understanding. The collaboration process of sharing knowledge is an important element that must be planned well (Lai et al., 2020). Knowledge shared in a structured manner creates alignment between the company's and collective goals in the supply chain by involving all components (Ali et al., 2024). Thus, decisions can benefit all parties involved (Hao et al., 2024). Understanding each partner's organizational performance is also key to collaboration success (Jain et al., 2023). Each party must have sufficient information regarding its contribution to the overall performance of the supply chain (Dubey et al., 2019). This understanding allows for adjusting actions aligned with common goals so that collaboration can run more effectively.

The success of collaboration in decision-making also relies heavily on effective communication among supply chain partners (Wang et al., 2023b). Transparent communication helps prevent miscommunication, speed up problem resolution, and ensure everyone stays on the same track. With good communication, collaboration can run more smoothly and provide optimal results (Wang et al., 2023a). Ultimately, collaborative decision-making is a complex but essential process in logistics and supply chains (Nematollahi et al., 2017). Supply chain partners can create added value by sharing responsibilities, sharing knowledge, and maintaining effective communication. This process not only improves operational efficiency but

also builds stronger relationships among partners (Wang et al., 2023b), thereby supporting the achievement of sustainable long-term goals (Tarigan, 2018). In essence, collaboration aims to achieve common goals by helping each other.

2.3. Supply Chain Flexibility

Business strategy is flexible with the company's ability to grow and adapt to a business environment that is constantly changing and difficult to predict (Yu et al., 2018). Business flexibility is a requirement that companies can meet to be responsive to the needs of external partners (Siagian et al., 2021). Companies constantly strive quickly to change continuously in uncertain changes but can adapt with high flexibility (Rojo et al., 2018). The company's ability to build good cooperation with suppliers and have adequate quality so that it can provide raw materials by the requirements that have been set (Basana et al., 2025). Companies can pay attention to and identify and monitor the delivery performance of suppliers (Nagarajan et al., 2013). The company can identify the performance of suppliers in providing materials. The provision of materials according to the company's needs from suppliers can be fulfilled properly, but it is still difficult to meet customer needs continuously, even in a stable environment (Harianto et al., 2024). Companies may also have problems with the availability of information from external partners. The ability of companies to maintain a balance with suppliers, partners, and customers dynamically as a supply chain of flexibility (Willis et al., 2016). Company management needs to understand the correlation process between components in the supply chain to quickly respond to changes that occur to suit the company's conditions (Chaudhuri et al., 2018). Changes that occur externally of customers can be understood quickly internally by adjusting to internal conditions. Companies can maintain internal conditions by adjusting the amount of inventory and the company's distribution speed (Sarkar & Seo, 2021). The information companies obtain quickly, accessing data and reports as needed, can detect external changes to make appropriate decisions (Somon et al., 2019; Arikat, 2024). The availability of access to information in the company that all departments get quickly and appropriately is a condition for meeting supply chain flexibility (Shukor et al., 2021).

Companies already have many departments related to data needs and can share data with other departments in real time (Singh & Kumar, 2021). Supply chain practices in companies can provide real-time data access for stakeholders, departments, and external partners (Ali et al., 2024). Supply chain flexibility is closely related to the company's ability to implement programs established as a production system (Sarkar & Seo, 2021). The company's speed in implementing the decisions that have been set can overcome the problems (Dubey et al., 2019). The company has sought to improve its ability to change its strategy and operations to implement the required strategies (Tarigan et al., 2024). The company strives to involve every member of the supply chain to be able to respond to changes that occur externally. The involvement of members in the supply chain flow to make a quick response that is very volatile by increasing flexibility is a capability that must be maintained (Yu et al., 2018).

2.4. Operational performance

A company's performance reflects the level of achievement in implementing programs, activities, or policies in realizing predetermined goals (Siagian et al., 2021). Company performance is the achievement of results or actions from an activity or process carried out in a certain period (Basana et al., 2025). Evaluation of company performance is essential to ensure that resources, such as manpower, capital, and technology, are utilized effectively and efficiently (Yu et al., 2018). The company's performance is an evaluation to provide an overview of the extent to which the company has achieved the strategic goals that have been set (Willis et al., 2016). More specifically, operational performance refers to the effectiveness and efficiency of the company in carrying out operational activities (Wu et al., 2014). Operational performance is measured through various indicators, such as productivity, quality, speed, and flexibility. The purpose of measuring operational performance evaluation is to evaluate the extent to which operational activities have supported achieving the company's strategic objectives and identify opportunities to improve operational processes (Kumar et al., 2018). Applying best practices is one of the important approaches to improving operational performance (Soesetyo et al., 2024). Operational performance evaluation can include applying methods or standards that have proven effective in achieving operational efficiency and effectiveness (Harianto et al., 2024). By implementing best practices, companies can improve the organization's ability to produce products or services that provide added value to customers (Lai et al., 2020). Sustainable organizational efficiency is also the key to improving the company's competitiveness in the global market (Truong et al., 2017). In manufacturing companies, operational performance is often measured by comparing the output produced and the inputs used (Tarigan & Siagian, 2021). The output includes the number of products, product quality, and customer satisfaction. Operational performance also includes implementing managerial activities, such as planning, designing, updating, operating, and supervising production systems. This process ensures the company can achieve maximum efficiency in running its operations (Tarigan, 2018). Integrating operational performance with supply chain processes is an important strategy for improving the efficiency and effectiveness of companies (Kumar et al., 2018). This integration includes collaboration between various functions in the supply chain to improve customer service by speeding up the delivery process. The company's operational performance can be emphasized by improving reliability and creating flexibility in changing market demands. Effective operational management practices also focus on managing the company's resources (Truong et al., 2017). The company's operational performance includes efficient inventory and warehouse

management with a well-organized capacity (Soesetyo et al., 2024). This integrated management system helps companies meet customer needs effectively, improves cost efficiency, and reduces waste (Yu et al., 2018). Thus, good operational management is one of the key elements in supporting optimal operational performance (Wang et al., 2023a).

2.5. Relationship between research concepts

2.5.1. Human-machine interface and collaborative decision-making

Human-machine interface (HMI) is a technology that allows interaction between humans and machines through hardware and software (Beltramini, 2018). Companies using HMI can find out the results of the production process in real-time, which is integrated with system information technology (Morgan et al., 2021) to produce reports so that it is easy to analyze and can be shared with internal and external partners in determining collaborative decision making (Haesevoets et al., 2021; Jiang, 2020). HMI, combined with a collaborative decision-making approach, has a strategic role (Hao et al., 2024) in integrating machine analytical capabilities to support more effective decision-making (Ansari et al., 2018). Internal and external collaboration can increase the speed of the decision-making process with the accuracy and relevance of the results (Li et al., 2023). HMI helps humans understand complex information through interactive real-time data visualization (Cao et al., 2021; Jain et al., 2023). HMIs allow for dynamic interactions, where users can provide direct feedback that allows the system to adjust to needs (Zhang et al., 2024). The synergy between humans and machines strengthens the reliability of decisions (Wu et al., 2022) by combining big data-based analytics possessed by machines with human contextual considerations (Xiong et al., 2023). HMI integrates systems automatically by improving safety and efficiency (Mustafa et al., 2023; Mourtzis et al., 2023). A statement of research hypothesis can be established

H_1: *Human-machine interface affects collaborative decision making.*

2.5.2. Human-machine interface and supply chain flexibility

Human-Machine Interface (HMI) has become a key element in supporting supply chain flexibility in various industries (Liu et al., 2024). Human-machine interfaces can provide fast and accurate data related to the availability of raw materials and the sustainability of the production process, thus impacting supply chain flexibility to respond to unexpected changes in the market and customer demand. HMI enables integration between humans and automated systems (Jeng et al., 2021) to create a more adaptive, responsive, and efficient supply chain (Haesevoets et al., 2021). The role of HMI in supply chain flexibility lies in its ability to provide real-time data visualization, such as inventory levels and logistics movements. HMI can assist companies in assessing the performance of suppliers that have been determined so that it impacts supply chain flexibility in estimating demand and reducing the risk of uncertainty (Arikat, 2024). Companies can monitor the supply chain process and make strategic decisions based on accurate and up-to-date information (Falandays et al., 2021). HMI allows companies to interact directly with the system (Xiong et al., 2023) to provide input or make quick adjustments in situations requiring sudden changes. HMI is important in maintaining operational continuity by increasing flexibility by using robotic systems (Kosicki & Thomessen, 2013). HMI can be used flexibly to control production lines according to changing demand (Li et al., 2023). HMI helps companies manage shipments dynamically by ensuring delivery efficiency and reducing the risk of delays. HMI supports better coordination with dynamic partners (Mustafa et al., 2023) so companies can easily adjust supplies to local needs. Integration of HMI with supply chain flexibility by increasing the speed of response to change, reducing downtime, and meeting customer needs more effectively (Zhang et al., 2024). The application of HMI in supply chain flexibility faces the challenges of large initial investment requirements (Morgan et al., 2021), the complexity of integration with existing systems, and user training to make the most of this technology (Mourtzis et al., 2023). A statement of research hypothesis can be established

H_2: *Human-machine interface influences supply chain flexibility.*

2.5.3. Human-machine interface and operational performance

Human-Machine Interface is a technology that allows interaction between workers and machines through interfaces that can be easily used and understood (Beltramini, 2018). HMIs can be used to monitor, control, and manage complex machine operating systems (Bouyam & Punsawad, 2022; Jeng et al., 2021) so that it has an impact on operational performance (Haesevoets et al., 2021). The role of HMI is vital in ensuring operational efficiency and effectiveness because it can visualize operational data in real-time. Integrating workers with machines as a form of HMI (Li et al., 2023), can result in a more efficient and effective data collection process in its operations (Cao et al., 2021). Operational performance is the ability of an organization to use an HMI system to achieve efficiency and effectiveness in its operations (Wang et al., 2023a). HMI significantly improves operational performance through appropriate decision-making mechanisms (Falandays et al., 2021). This technology allows for faster decision-making due to the data provided in real-time (Zhang et al., 2024). In addition, HMI helps improve operational efficiency by automating manual tasks (Xiong et al., 2023) so that reducing the time required can result in the company's operational performance. HMI can provide convenience for workers in operating machines and other equipment so that the risk of errors is small (Somon et al., 2019) and idle time is reduced, improving

operational performance. HMIs can support proactive maintenance by providing early warnings of machine conditions, thereby reducing the risk of downtime (Jain et al., 2024). Implementing HMI in the company's operations has shown that the production process has improved operational performance (Kosicki & Thomessen, 2013). With HMI, the company can centrally monitor and control the production process and improve the accuracy of production process measurements (Bouyam & Punsawad, 2022). HMI is expected to be increasingly integrated with Internet of Things (IoT) technology, artificial intelligence (AI), and big data analytics (Mourtzis et al., 2023; Arikat, 2024). This integration improves operational efficiency and supports collaborative decision-making (Jiang, 2020). Adopting HMI is important for companies to achieve operational excellence in an increasingly competitive business environment (Morgan et al., 2021). A statement of research hypothesis can be established

H_3: *Human-machine interface affects operational performance.*

2.5.4. Collaborative decision making and supply chain flexibility

Collaborative decision-making is a strategic approach that involves internal and external partners in the decision-making process together to achieve optimal goals (Wang et al., 2023a). Collaborative decisions enable companies to respond quickly and effectively to challenges (Cao et al., 2021). Collaborative decision-making plays an important role in improving the ability of supply chain flexibility to adapt to changes in the business environment, market demand, or operational disruptions (Wang et al., 2023b). Supply chain flexibility refers to a company's ability to adapt its processes to changes (Rojo et al., 2018). Companies must change quickly due to fluctuations in demand and delays in the delivery of raw materials (Levalle & Nof, 2015). Collaborative decision-making supports flexibility by strengthening communication and coordination between various parties in the supply chain (Nematollahi et al., 2017). Close collaboration with internal and external partners in making strategic decisions using comprehensive data and analysis (Daghar et al., 2021). Collaborative decision-making ensures a faster and more accurate response (Hao et al., 2024) to changes in the situation to increase supply chain flexibility (Nagarajan et al., 2013). A collaborative decision-making approach in supply chain flexibility with increased adaptability reduced disruption risk and higher operational efficiency (Jiang, 2020). By involving various stakeholders in the decision-making process, companies can improve the accuracy of decisions and ensure that every action is based on a common goal. Collaborative decision-making in supply chain flexibility is needed to determine the need to build trust between stakeholders, integrate supporting technologies, and ensure that all parties have adequate skills and knowledge (Ali et al., 2024). Collaborative decision-making and supply chain flexibility are strategic combinations that deal with global market dynamics (Long, 2016). By building effective collaboration, companies can create a resilient and responsive supply chain (Lai et al., 2020). In addition, the company's ability to synergize supply chain flexibility with collaborative decision-making can face increasingly complex challenges while providing added value to customers (Tarigan et al., 2024). A statement of research hypothesis can be established.

H_4: *Collaborative decision-making affects supply chain flexibility.*

2.5.5. Collaborative decision-making and operational performance

Collaborative decision-making (CDM) is important in determining the common interests of supply chain partners in determining decision-making in producing supply chain performance (Kumar et al., 2018). The company tries to involve various functions within the organization or external partners such as suppliers, customers, or other third parties in determining critical activities so that there are no obstacles in the production department and operational results can be maintained stably (Jiang, 2020). Collaboration allows companies to share information with internal partners and even with external partners in anticipation of market changes to stabilize the company's operational performance (Long, 2016). Companies can build cooperation with partners in collaborating to produce decisions that have a shared perspective to produce improved operational performance (Wang et al., 2023b). Companies can share resources with partners to achieve better collaborative decisions, resulting in high efficiency (Wu et al., 2014). Collaborative decision-making is becoming increasingly relevant in a complex modern business environment with operational challenges requiring a cross-functional and cross-organizational approach that results in improved operational performance. The collaborative decision-making process allows alignment between various organizational units (Nematollahi et al., 2017), thereby reducing the potential for conflicts or inconsistencies in operational implementation to maintain stable operational performance. Collaborative decision-making encourages innovation by leveraging diverse ideas (Jain et al., 2023) and perspectives from stakeholders that contribute to improved operational efficiency and effectiveness. Collaborative decision-making determines the impact of increasing the speed and accuracy of decision-making to improve operational performance (Jiang, 2020). Collaborative decision-making also strengthens relationships in the supply chain through better communication, helping reduce operational disruption risk (Hao et al., 2024). Companies that have collaborative decision-making involve suppliers in the production planning process and can ensure the availability of raw materials on time (Lai et al., 2020), contributing to improved service timeliness. Industrial sector case studies show that collaborative decision-making in production planning and supply chain management can improve operational performance. A statement of research hypothesis can be established.

H_5: *Collaborative decision-making impacts operational performance.*

2.5.6. Supply chain flexibility and operational performance

Supply chain flexibility allows companies to improve operational performance (Chaudhuri et al., 2018) because it has the ability of the supply chain to respond to changes in demand, disruptions, or market uncertainty quickly and efficiently (Willis et al., 2016). The company's supply chain flexibility in procurement, production, and distribution can result in accurate product delivery as the company's operational performance (Siagian et al., 2021). Companies' ability to adjust product capacity can improve operational performance and delivery times (Tarigan & Siagian, 2021). Operational performance is obtained by companies carrying out their operations effectively and efficiently by maintaining high flexibility (Dubey et al., 2019). Supply chain flexibility impacts operational performance (Ali et al., 2024), allowing companies to manage changes and disruptions without sacrificing operational processes. The company's flexibility in involving company partners so that the procurement of raw materials can be anticipated not to be late. Companies can control stock levels by increasing flexibility to satisfy customers (Harianto et al., 2024). The company's flexibility in production allows it to adjust production capacity according to fluctuations in demand (Rojo et al., 2018), thereby increasing efficiency and reducing waste (Sarkar & Seo, 2021). Flexibility in distribution allows companies to adjust delivery times and methods, which impacts increasing customer satisfaction (Yu et al., 2018). Company flexibility can be developed by periodically investing in technology, infrastructure, and training to maintain stable and even improved operational performance. Coordination between various parties in the supply chain can be advantageous if managed properly (Truong et al., 2017). Companies need to ensure that the flexibility built is balanced with the costs incurred to ensure the sustainability of long-term benefits (Shukor et al., 2021). A statement of research hypothesis can be established

H_6: *Supply chain flexibility affects operational performance.*

2.5.7. Human-machine interface and operational performance through the collaborative decision making and Supply chain flexibility

The success of HMI implementation in improving operational performance is influenced by how decision-making is carried out within the organization and can involve external partners (Cao et al., 2021). Collaborative decision-making involves various parties, both internal and external, in the decision-making process (Lai et al., 2020), thus allowing the use of data generated by HMI more effectively and strategically and impacting production stability that maintains operational performance. HMI, combined with collaborative decision-making, focuses on data to be more coordinated and on target, resulting in operational performance (Jiang, 2020). Various internal functions of the organization can use operational data generated by HMI and can be shared with external partners in formulating joint strategies that support operational efficiency (Siagian et al., 2021). CDM also ensures that information from HMIs can be utilized technically and integrated with strategic actions that improve overall operational performance. In the manufacturing sector, it shows that companies that integrate HMI with CDM can improve operational performance. Operational performance is influenced by the organization's ability to utilize HMI technology to support daily operations and make them more flexible. The effectiveness of HMI in improving operational performance is often determined by supply chain flexibility (Dubey et al., 2019), which is the ability to respond quickly and efficiently to changes in demand, disruptions, or market fluctuations. Supply chain flexibility can strengthen the relationship between HMIs and operational performance (Liu et al., 2024) by providing better adaptability to the data and insights generated by HMIs (Liu et al., 2024). The company's ability to use HMI provides real-time data for accurate monitoring and control of operational activities. Operational performance is influenced by the organization's ability to utilize HMI technology to support daily operations and make them more flexible. The effectiveness of HMI in improving operational performance is often determined by supply chain flexibility (Jeng et al., 2021) by responding quickly and efficiently to changes in demand, disruptions, or market fluctuations (Shukor et al., 2021). Supply chain flexibility can strengthen the relationship between HMI and operational performance by providing better adaptability to the data and insights generated by HMIs. The company's ability to use HMI provides real-time data for accurate monitoring and control of operational activities. The data generated by HMI on demand fluctuations can be integrated with supply chain flexibility to adjust production capacity and delivery schedules, thereby improving service timeliness and minimizing disruptions in the supply chain. Manufacturing companies use HMI to monitor production efficiency and integrate it with supply chain flexibility through supplier diversification and flexible delivery schedules (Harianto et al., 2024). HMI technology and the development of supply chain flexibility can reduce operational costs because it obtains data in real-time. Coordination between organizational functions and external partners in the supply chain flexibility can be effective when using HMI to optimize production processes, thereby improving operational performance.
A statement of research hypothesis can be established

H_7: *The human-machine interface influences operational performance mediated by collaborative decision-making.*
H_8: *The human-machine interface affects operational performance and is mediated by supply chain flexibility.*
H_9: *The human-machine interface impacts operational performance through collaborative decision-making and supply chain flexibility.*

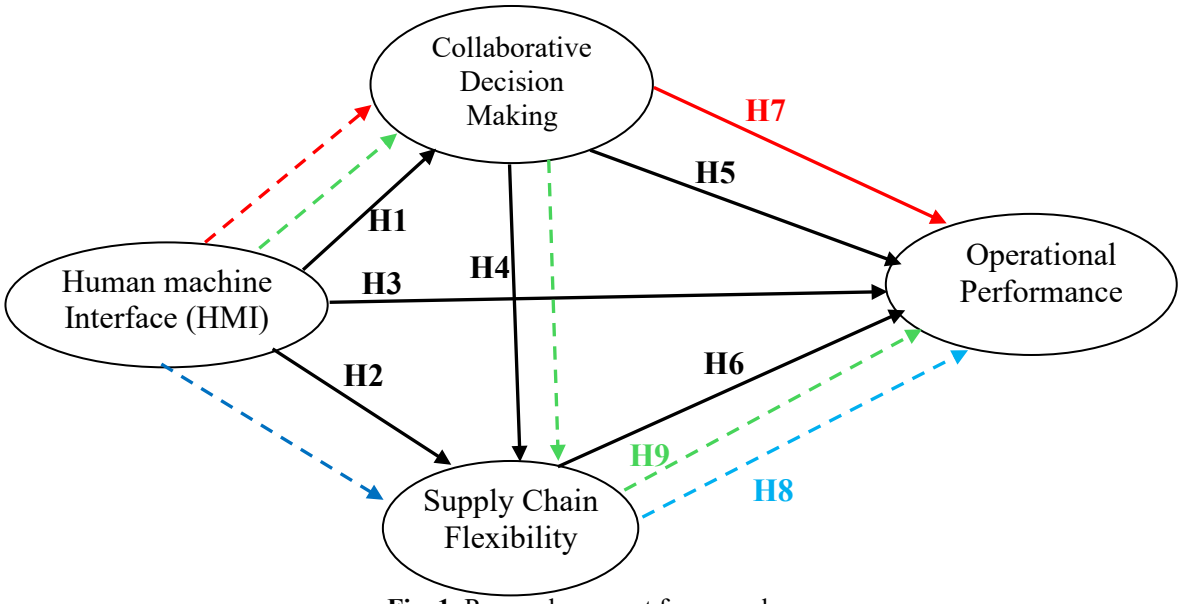

Fig. 1. Research concept framework

3. Research Methods

Data collection in the study was carried out by distributing questionnaires offline and online. The researcher collected data on manufacturing companies on the island of Java by taking several companies representing each province in Java. Data collection was conducted online by sending questionnaires via email and WhatsApp to respondents so they could understand the substance of the research. The researcher gave the respondents 1 to 2 weeks to understand. Then, the researcher contacted the practitioners to have a meeting to assess and perform face validity related to the content of the questionnaire. Seventy-six (76) respondents have responded to the offline data collection process and answered all the questionnaire questions. Meanwhile, data is also collected online by making a Google form questionnaire distributed by the faculty students to deliver the questionnaire to practitioners in Java. The researcher trained students to understand the requirements of being a respondent and was given a dissemination time for 2 semesters of about ten months. Each student is given 2-3 respondents to collect data from practitioners, with the criteria of manufacturing businesspeople with more than 20 employees and respondents who have become permanent employees, at least as junior staff with 1 year of work experience. Four hundred sixty (460) questionnaires were distributed online through Google form and, according to the predetermined criteria. As many as 427 respondents have completed the questionnaires correctly. In contrast, 33 others did not meet the criteria because 21 had less than 1 year of work experience, and 12 respondents were contract workers, not permanent employees. The total number of questionnaires that can be further processed is 503 questionnaires. The demographics of the respondents are shown in Table 1. Table 1 shows that males 366 (73 %) and females 137 (27 %). Males are more due to trait work with machines in the production area, so many companies need males because of the characteristics of the work on the production floor. The most significant part of the work came from the production department, which is directly related to machinery and production processes, with 178 respondents (35%) followed by the warehouse, as many as 105 respondents (21%) related to raw materials and machine spare parts in the production area and the third in the engineering department as many as 93 respondents (18%). Demographics based on workplace positions are highest in managers and supervisors, with 324 respondents (64%). These two positions are directly responsible for all production processes and company operations, so they are very close to supply chain operations and human interface and can make decisions collaboratively. The profile of respondents in the working period was obtained the most in more than 8 years of work experience, namely 302 respondents (60%). This condition shows that respondents have experience in company operations and have often collaborated in making joint decisions. The largest educational profile is found in undergraduates, with 263 respondents (52%). Meanwhile, the demographics with the largest number of employees between 20-60 amounted to 223 (44%), and the category of large companies with more than 100 employees amounted to 179 (36%). The characteristics of manufacturing companies determined by the majority came from consumer goods manufacturing companies with 141 respondents (28%), followed by manufacturing companies engaged in woodworking/furniture as many as 103 respondents (20%).

Research with a variable human-machine interface is an interface between humans and machine technology that can make the two collaboratives in a system able to produce performance. The human-machine interface is set with five measurement items, namely easy-to-obtain production process data (HMI1), easy-to-control production process (HMI2), easy-to-monitor production process (HMI3), complete production process report (HMI4) and real-time production data (HMI5). Collaborative decision-making involves internal and external partners in improving coordination and integration in the supply chain. Collaborative decision-making is determined with five measurement items, namely planning decisions involving customer partners (CDM1), involving partners in solving production problems (CDM2), information data shared with partners to facilitate decision-making (CDM3), communicating company decisions with external partners (CDM4) and joint decisions with partners in anticipating market changes (CDM5).

Table 1
Demography of Respondent

Respondent profile	Description	Frequency	%
Gender	Female	137	27
	Male	366	73
Department	Engineering	93	18
	Finance & Accounting	9	2
	Marketing	37	7
	Planning Production	44	9
	Production	178	35
	Purchasing/Procurement	37	7
	Warehouse	105	21
Position at work	Owners	46	9
	Director/General Manager	23	5
	Manager	176	35
	Superintendent	34	7
	Supervisor	148	29
	Staff	76	15
Working experiences in the Company	1 to < 3 Years	47	9
	3 to < 5 Years	67	13
	5 to < 8 Years	87	17
	8 to < 11 years	129	26
	11 Years More	173	34
Education level	High school equivalent	92	18
	Diploma Equivalent	116	23
	Graduate level	263	52
	Post-graduate level	32	6
Number of Workers	20 s/d < 60 employees	223	44
	60 s/d < 100 employees	101	20
	Over 100 employees	179	36
Manufacturing Industry sector	Chemical, Pulp & Papers	35	7
	Information, Telecommunication & Communication	56	11
	Consumer Goods	141	28
	Plastic	76	15
	Textile	48	10
	Transportation, Machinery	44	9
	Woods working/furniture	103	20

Supply chain flexibility is the company's ability to respond to external and internal changes in the supply chain flow. Measurement items for supply chain flexibility are determined by flexible production processes (SCF1), flexible planning processes (SCF2), flexible labor placement (SCF3), flexible material procurement (SCF4), flexible delivery (SCF5), and flexible inventory levels (SCF6). Fourth, operational performance is the achievement of an activity or process's results or actions in a certain period. Operational performance is determined by measuring items such as reduction in production lead time (OP1), on-time delivery (OP2), increased response to customers (OP3), number of products following customer demand (OP4), and product quality following requirements (OP5). The data analysis used to answer the entire hypothesis was Smart-PLS software version 4.0.

4. Analysis and Discussion

The research in conducting the analysis using PLS by testing the inner and outer models. The first test is used with the inner model, namely the validity and reliability of survey testing in Table 2. The inner model test in Table 2 was obtained by testing the validity shown on the loading factor value for all measurement items greater than 0.500. The lowest loading factor value in HMI3 was 0.653 (>0.500), Collaborative decision-making had the lowest loading factor in CDM3 of 0.798 (>0.500), Supply chain flexibility had the lowest loading factor in SCF4 of 0.527 (>0.500), dan operational performance with the lowest loading factor on OP3 of 0.604 (>0.500). The loading factor met the set requirements, and the Average Variance Extracted (AVE) was greater than 0.500. The second loading factor test, the reliability test, is determined by the Cronbach alpha value, and the composite reliability exceeds 0.700. Table 2 shows the Cronbach alpha value of 0.832 and composite reliability of 0.848 for the human-machine interface; collaborative decision-making has a Cronbach alpha of 0.902 and composite reliability of 0.905; Supply chain flexibility has a Cronbach alpha of 0.789 and composite reliability of 0.806 and finally variable operational performance Cronbach alpha of 0.740 and composite reliability of 0.766. The outer loading test met the requirements so that the inner model analysis could be carried out to obtain a research hypothesis. The testing result of the first research hypothesis (H1) to the ninth (H9) is shown in the full model of the research results in Fig. 2 and the hypothesis testing results in Table 2. Based on Table 3, the first hypothesis (H1) was obtained that the human-machine interface affected collaborative decision-making of 0.559 with a t-statistics value of 14.939 (p-value 0.000), then the first hypothesis was accepted. The results of the first hypothesis show that the human-machine interface significantly affects collaborative decision-making. Manufacturing companies can provide complete production process reports, and production data is obtained in real-time as a human-machine interface to determine faster and more accurate collaborative decision-making by involving customer partners in planning and solving production problems. The results of the study support the results of the study that state that the human-machine interface affects collaborative decision-making (Haesevoets et al., 2021; Jiang, 2020; Ansari et al., 2018; Cao et al., 2021; Jain et al., 2023; Mustafa et al., 2023; Mourtzis

et al., 2023). The second hypothesis (H2) that the human-machine interface affects supply chain flexibility is 0.490 with a t-statistics value of 11.053 (p-value 0.000), then the second hypothesis is accepted. Manufacturing companies in Indonesia, especially on the island of Java, implement human-machine interfaces with production processes that are easy to monitor with automatic machines, and production data obtained in real-time influence increasing supply chain flexibility. This condition can be seen in the company's ability to deliver flexibly according to demand and supported by a flexible production process. The results of the study support the results of research that state that the human-machine interface affects supply chain flexibility (Liu et al., 2024; Arikat, 2024; Kosicki & Thomessen, 2013; Li et al., 2023; Mustafa et al., 2023; Morgan et al., 2021; Mourtzis et al., 2023).

Table 2
Outer model validity and reliability

Item of Research	Factor loading	Cronbach Alpha	Composite Reliability	AVE
Human-machine interface		0.832	0.848	0.600
HMI1 (Production process data is easy to obtain)	0.785			
HMI2 (Easy-to-control production process)	0.758			
HMI3 (Easily monitored production process)	0.653			
HMI4 (Complete production process report)	0.852			
HMI5 (Production data obtained in real time)	0.810			
Collaborative decision-making		0.902	0.905	0.720
CDM1 (Planning decisions involving customer partners)	0.886			
CDM2 (The company involves partners in solving production problems)	0.841			
CDM3 (Information data shared with partners to facilitate decision-making)	0.798			
CDM4 (communicating company decisions with external partners)	0.843			
CDM5 (Joint decisions of partners in anticipation of market changes)	0.872			
Supply chain flexibility		0.789	0.806	0.853
SCF1 (Flexible production process)	0.777			
SCF2 (Flexible planning process)	0.561			
SCF3 (Flexible workforce placement)	0.767			
SCF4 (Flexible material procurement)	0.527			
SCF5 (Flexible delivery)	0.847			
SCF6 (flexible inventory level)	0.700			
Operational performance		0.740	0.766	0.828
OP1 (production lead time reduction measurement)	0.640			
OP2 (On-time delivery)	0.628			
OP3 (Response to customers increases)	0.604			
OP4 (Number of products according to customer demand)	0.825			
OP5 (Product quality according to requirements)	0.792			

Table 3
Results of hypothesis testing

Path Coefficient	Coefficient	T statistics	P values
Human Machine Interface (HMI) → Collaborative Decision Making (H1)	0.559	14.939	0.000
Human Machine Interface (HMI) → Supply Chain Flexibility (H2)	0.490	11.053	0.000
Human Machine Interface (HMI) → Operational Performance (H3)	0.340	6.609	0.000
Collaborative Decision Making → Supply Chain Flexibility (H4)	0.375	8.887	0.000
Collaborative Decision Making → Operational Performance (H5)	0.149	2.679	0.007
Supply Chain Flexibility → Operational Performance (H6)	0.381	6.754	0.000
Human Machine Interface (HMI) → Collaborative Decision Making → Operational Performance (H7)	0.083	2.625	0.009
Human Machine Interface (HMI) → Supply Chain Flexibility → Operational Performance (H8)	0.187	5.417	0.000
Human Machine Interface (HMI) → Collaborative Decision Making → Supply Chain Flexibility → Operational Performance (H9)	0.080	5.014	0.000

Table 2 shows that the third hypothesis (H3) obtained that the human-machine interface had an effect on operational performance of 0.340 with a t-statistics value of 6.609 (p-value 0.000), then the third hypothesis was accepted. The production process is easy to monitor, and production process data is easy to obtain and control as a human-machine interface impacts operational performance. The improvement in operational performance is found in the measurement of reduced production lead time and increased response to customers. The results of the study confirm the results of the study that stated that the human-machine interface affects operational performance (Beltramini, 2018; Cao et al., 2021; Wang et al., 2023a; Falandays et al., 2021; Kosicki & Thomessen, 2013; Morgan et al., 2021). The fourth hypothesis (H4), determined by collaborative decision-making, affected supply chain flexibility of 0.375 with a t-statistics value of 8.887 (p-value of 0.000), and the fourth hypothesis was accepted. Planning decisions involving customer partners and communicating company decisions with external partners as a form of collaborative decision-making impact supply chain flexibility. Companies can create increased supply chain flexibility in flexible production processes and flexible material procurement. The results of the study support the results of previous research on collaborative decision-making influencing supply chain flexibility (Wang et al., 2023b; Long, 2016; Ali et al., 2024; Nagarajan et al., 2013). The fifth hypothesis (H5), determined by collaborative decision-making, affects the operational performance of 0.149 with a t-statistics value of 2.679 (p-value 0.007), then the fifth hypothesis is declared accepted. Collaborative decision-making with shared data and information facilitates decision-making and, together with partners anticipating market changes, can impact operational performance. This condition shows a reduced production lead time and the number of products following customer demand adequately.

The research supports the results of previous research that states that collaborative decision-making affects operational performance (Kumar et al., 2018; Wu et al., 2014; Nematollahi et al., 2017; Jain et al., 2023; Hao et al., 2024; Lai et al., 2020). The sixth hypothesis (H6) has been determined to be that supply chain flexibility affects the operational performance of 0.381 with a t-statistics value of 6.754 (p-value 0.000). Then, the sixth hypothesis is declared accepted. Supply chain flexibility, shown by flexible planning processes, flexible production, and flexible workforce placement, affects operational performance with increased on-time delivery and increased response to customers. The results of the study support the results of previous research that stated that supply chain flexibility affects operational performance (Chaudhuri et al., 2018; Willis et al., 2016; Siagian et al., 2021; Dubey et al., 2019; Tarigan & Siagian, 2021; Dubey et al., 2019; Harianto et al., 2024; Yu et al., 2018; Shukor et al., 2021). The results show intervening variables with collaborative decision-making and supply chain flexibility between human-machine interface and operational performance. Table 2 shows that the seventh hypothesis (H7) is obtained by the human-machine interface on operational performance with collaborative decision-making as an intervening variable as 0.083 with a t-statistics value of 2.625 (p-value 0.009), then the seventh hypothesis is accepted. The company's ability to obtain production data in real-time can produce planning decisions involving external partners and communicate the company's decisions to impact on customer response, ultimately increasing production products by demand orders and timely delivery. The eighth hypothesis (H8), determined by the human-machine interface on operational performance with supply chain flexibility as an intervening variable, was obtained at 0.187 with a t-statistics value of 5.417 (p-value of 0.000), then the eighth hypothesis was accepted. The company's human-machine interface makes the supply chain flexible with flexible labor placement and inventory levels able to produce operational performance with timely delivery and product quality according to requirements. Table 2 shows that the human-machine interface's ninth hypothesis (H9) on operational performance with collaborative decision-making and supply chain flexibility as an intervening variable of 0.080 with a t-statistics value of 5.014 (p-value of 0.000) is accepted.

The ability of manufacturing companies to design production processes with human-machine interfaces makes fast and accurate production system reporting impact strategic decision-making that can adjust to external conditions. The Company can manage the Decisions set according to internal and external conditions to increase flexibility in internal and external partners. The manufacturing industry can empower partners to increase supply chain flexibility with flexible production processes and flexible workforce placement. Increasing supply chain flexibility owned by the company and supported by external partners can increase supply chain flexibility to produce timely deliveries and increase customer response. The company's precision in accommodating customer needs will provide adequate satisfaction and good competitiveness, so operational performance has improved. The company can maintain good operations by using a human-machine interface, which can increase supply chain flexibility with improved performance. The practical contribution of research to companies by improving machine automation to obtain data in real-time with adequate reports to facilitate collaborative strategic decision-making in producing operational performance. The theoretical contribution of research can enrich the supply chain management theory and the resource-based view of producing competitiveness.

5. Conclusion

This study aims to investigate the impact of the human-machine interface on collaborative decision-making and supply chain flexibility in improving operational performance in the manufacturing sector in Indonesia. This study has proposed eight hypotheses to be investigated. The results indicate that all proposed hypotheses were supported. The human-machine interface positively enables collaborative decision-making (H1) and supply chain flexibility (H2) and improves operational performance (H3). Besides, Collaborative decision-making supports supply chain flexibility (H4) and improves operational performance (H5). Moreover, supply chain flexibility positively improves operational performance (H6). Finally, the Human-machine interface directly improves the operational performance. Data analysis also shows that manufacturing companies in East Java have extensively used machines controlled by system automation. This condition allows the company to obtain data in actual production and increases production capacity. The company's ability to make an integrated production process makes changes for internal and external partners. The human-machine interface that has been used by the company and integrated with the company's system can provide complete production process reports, and the ease with which the production process is controlled can produce collaborative decision-making. Companies can involve customer partners in planning decisions and solving production problems, influencing supply chain flexibility and operational performance. Companies can involve partners in determining their role in supply chain flexibility in a flexible planning process and determining flexible inventory levels to produce the number of products according to customer demand and timely delivery. Human machines that occur in manufacturing companies in Indonesia, especially on the island of Java, which have applied many human-machine interfaces by increasing human-machine interaction through system automation, can influence collaborative decision-making and supply chain flexibility in producing company operational performance. Manufacturing companies maintain operational performance so that it can be maintained, and technology is applied to make the production process partially or fully automated to increase the company's competitiveness.

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