

Uncertain Supply Chain Management

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The influence of supply chain integration on firm performance through lean manufacturing, green supply chain management and risk management

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ABSTRACT

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The rapid development of technology has enabled companies to integrate internal and external partners working together in the supply chain network. Supply chain integration allows fast information to facilitate real-time and reliable decision-making. This study investigates the role of supply chain integration on firm performance through adopting lean manufacturing, green supply chain management, and risk management. The study surveyed manufacturing companies implementing ISO 14000 to represent green supply chain management and integrated information technology as a form of integration. The questionnaires were distributed using a Google form, and 93 valid responses were obtained. Data analysis employed a partial least square approach with SmartPLS software 4.1 version. The data processing results found that supply chain integration increased lean manufacturing by 0.684, green supply chain management by 0.451, and supply chain risk management by 0.333. Lean manufacturing companies using a continuous process control system and process improvements significantly improve green supply chain management by a path coefficient of 0.477, supply chain risk management by 0.206, and firm performance by 0.370. Green supply chain management significantly impacts supply chain risk management by a coefficient of 0.416 and firm performance by 0.189. Supply chain risk management with a system for detecting operational process risks and emergency procedures in overcoming changes in customer orders affects the increase in firm performance by 0.354. The practical contribution of research provides insight for practitioners to invest in information technology and adopt ISO 14000 implementation. Theoretical contributions in developing resources-based view theory in adopting green supply chain management and lean manufacturing.

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1. Introduction

Due to recent trending environmental sustainability issues, the manufacturing company has no choice but to build competitive advantages by adjusting policies to regulations set by the government and international standards (Siagian et al., 2023). Manufacturing companies must care about environmental issues when running their business (Wungkana et al., 2023). This relates to the globalization trend demanding that products comply with regulations or be sanctioned by the customers (Cherrafi et al., 2018). Therefore, manufacturing companies must integrate environmental principles into the supply chain practices, improving sustainability (Huo et al., 2019; Pham et al., 2023; Basana et al., 2022b). Businesses seeking economic sustainability integrate environmental principles by adjusting natural and business processes (Basuki et al., 2023; Siagian et al., 2023). Sustainable development refers to economic, environmental, and social growth and development to meet needs without compromising the ability of future generations to meet their own needs (Karmaker et al., 2023; Cherrafi et al., 2018).

Therefore, companies must adjust their policies and capabilities and collaborate with external parties (Basana et al., 2022b). This is important to build a sustainable supply chain through solid coordination with supply chain partners (Siagian et al.,

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2022b). Good supply chain coordination encourages reliable raw material procurement and product delivery (Basana et al., 2024). External parties and manufacturing companies must also build internal coordination to gain sustainable supply chain advantages (Siagian et al., 2022b). Technological advances have also changed the production process to produce reliable product delivery (Basana et al., 2024; Santoso et al., 2022). Research indicated that supply chain integration directly produces products that meet customer needs through the company's production process (Siagian et al., 2022b; Pirmanta et al., 2021) and must be able to meet the criteria set by customers (Pham et al., 2023). Sustainability in building collaboration with strategic partners will be mutually beneficial and help generate mutual benefits (Deshpande et al., 2012). Collaboration enables companies to control the whole process well and deliver products on time, which adds value to customers (Huo et al., 2019; Möldner et al., 2020; Tarigan, 2018). Manufacturing companies trying to build internal and external integration enable the company to eliminate non-value-added activities by adopting lean manufacturing practices (Möldner et al., 2020).

Moreover, collaboration helps companies adopt lean supply chain processes that focus on eliminating waste and increasing productivity and efficiency, resulting in competitive products with a competitive advantage (Tortorella et al., 2017). Research shows that lean manufacturing is essential for companies to produce superior products according to customer demand (Möldner et al., 2020). However, collaboration with the best suppliers and customers is required. This collaboration can be carried out with the concept of supply chain integration, which involves various related parties in the process of providing goods or services that are available on time, the right products as agreed together, with timely production processes by customer orders (Yuan et al., 2022; Freije et al., 2022; Dhaigude et al., 2020; Pirmanta et al., 2021). One component of supply chain integration Supplier integration is built by giving more roles to suppliers to be able to find out more detailed information in the company's internal (Eber et al., 2020) and involve suppliers in making plans to improve the company's lean manufacturing (Tse et al., 2018). The quality of these products is obtained by controlling the company's production process and the quality of raw materials supplied by the company's suppliers (Cherrafi et al., 2018; Noviasuti et al., 2024). Companies involved in supply chain integration can improve performance through improved customer service, internal operation efficiency, demand flexibility, new market development, and improved product development (Munir et al., 2020). Internal integration in the form of enterprise resources planning, supplier integration, and customer integration has an impact on improving green supply chain management (Siagian et al., 2021).

The company's internal integration as part of supply chain integration allows cross-functional integration integrated in real-time to produce fast and precise coordination to improve lean manufacturing (Dhaigude et al., 2020). Supply chain integration allows the company to adopt lean manufacturing and waste reduction (Hartono et al., 2023). Supply chain integration in companies can produce sustainable product development (Chen et al., 2018). Supply chain integration can help companies relate well with suppliers and clients by producing efficient and effective products and services as a form of lean manufacturing practice (Jabbour et al., 2014). Therefore, supply chain integration is essential for companies to improve agile operations, which is becoming an added value (Birasnav & Bienstock, 2019). In addition, supply chain integration is essential in implementing lean manufacturing, especially in internal integration, by reducing and even eliminating waste. Nevertheless, companies can build a flexible production system to avoid risks of excess stock and avoid employee strikes (Kumar et al., 2018). Supplier integration can eliminate the risk of uncertainty in providing raw materials delivery, while operational processes risk within the company is avoided by proper internal integration (Huma et al., 2020; Basana et al., 2024). Hence, supply chain integration correlates with supply chain risk management in anticipating environmental uncertainty (Zhu et al., 2017). Product greeners in green supply chain management are determined by risk and cost-sharing involving components involved starting from downstream and upstream (Wang et al., 2024). Supply chain risk in companies is guided by the information needed when running supply chain integration (Fan et al., 2017). Supply chain integration consisting of internal integration upstream and downstream integration improves green performance (Basana et al., 2022b), which enables manufacturing companies to produce environmentally friendly products by reducing waste and increasing customer value (Cherrafi et al., 2018).

Research proves that lean manufacturing set in manufacturing companies can enhance green supply chain management (Farias et al., 2019). In practice, lean manufacturing is closely related to green supply chain management in providing more value for manufacturing companies (Baumer-Cardoso et al., 2020). Moreover, lean practices in manufacturing companies can positively impact sustainable supply chains by improving environmental performance (Kosasih et al., 2023). The company's ability to manage lean well can impact the implementation of the green supply chain. Lean manufacturing in companies strives to reduce waste (Sunder & Prashar, 2024). The coordination formed between companies and partners in the lean supply chain can produce efficient products, services, and information by reducing waste (Golan et al., 2020). Lean manufacturing practice can provide increased resilience capability owned by healthcare companies by reducing waste (Alemsan et al., 2022). Lean production used by companies focuses on eliminating excessive activities and not providing value to the supply chain processes, which can improve the green supply chain by reducing pollution related to operations (Huang et al., 2023). Lean production shop floor by reducing process downtime and lean product development with design for manufacturability produced by the company impacts the quality process (Bubber et al., 2023). Lean production, originally applied to production workstations to supply chain systems, is called lean supply chain management (Tortorella et al., 2017).

Dealing with building supply chain integration in reducing supply chain risk is seen from two major perspectives: supply chain risk (demand side, production side, and supply side) and financial supply chain risk (Qiao & Zhao, 2023). Supply chain integration in manufacturing companies in India is determined by supply chain risk related to risks in the reliable raw material

procurement for key suppliers to determine company operations and impact timely product delivery to customers (Jajja et al., 2018). Dubey et al. (2018) stated the need for supply chain alignment between all components that have been integrated to be able to bear balanced risks accompanied by clear and balanced roles. Companies need to build proactive and reactive risk mitigation from the supply side so that the company's operational processes continue to run smoothly (Sturm et al., 2022). The company is reactive to overcome problems that occur quickly and stabilize operations (Pham et al., 2023). The integration is formed internally and externally to reduce risk by providing real-time information (Brusset & Teller, 2017). Internal integration enables supply chain risk management to adjust and recover capacity requirements (Riley et al., 2016). Meanwhile, internal integration allows coordination between departments using real-time information to reduce risks and sustain company operations (Munir et al., 2020). Supply chain risk management embraces all parties by coordinating the operation process, including the integrated process of risk identification (Shou et al., 2018). Supply chain integration with a digital system can impact supply chain risk by reducing disruptions to manufacturing supply, customer demand, and product cycles (Song et al., 2024). When combined with green supply chain management, lean manufacturing can generate economic returns by producing environmentally friendly products according to customer needs (Huo et al., 2019). Oliveira-Dias et al. (2023) stated that in generating extra value for customers, it is very important to reduce costs and manage variability to use resources efficiently (Oliveira-Dias et al., 2023). Lean management with just-in-time, set-up-time reduction, cellularized manufacturing, and waste management programs that are run together with green practice with waste management, reverse logistics, green manufacturing, eco-design, and life cycle assessment programs simultaneously affect supply chain performance by increasing cost reduction, value creation, and sustainability (Cherrafi et al., 2018). Lean manufacturing impacts innovation and operational performance (Möldner et al., 2020). Green supply chain practices can improve performance (Karmaker et al., 2023). Green manufacturing, part of the green supply chain in manufacturing companies, can impact operational performance (Siagian et al., 2023). Green purchasing, part of the green supply chain, improves green performance (Basana et al., 2022a).

Supply chain risk management is determined by preventing and responding to operation risk, improving operational efficiency, enhancing flexibility, and increasing financial performance (Shou et al., 2018). Supply chain risk management deals with controlling operation, supply, and demand risks that can downgrade operational performance (Pham et al., 2023). Company performance from product quality needs to be maintained and improved by manufacturing companies to continue to grow and develop in competition (Tse et al., 2018; Siagian et al., 2022a; Noviasuti et al., 2024). The company's performance in manufacturing companies is determined by customer satisfaction related to the quality of the finished products (Vanichchinchai, 2020). Supply chain integration can improve the company's ability to control risks by implementing effective supply chain risk management (Eber et al., 2020). The application of supply chain risk as a relationship between external partners and companies can jointly identify possible risk components. Well-controlled supply chain risk in the company impacts improving firm performance (Abeysekara et al., 2019). Supply chain risks faced by companies can vary.

The previous description addresses various research studies dealing with factors that could influence firm performance. However, all studies have focused desperately on factors that are related to the firm performance. Besides, the studies have been performed in various industry sectors, which is no guarantee that they work on different factors. Moreover, the current Global trend in environmental protection has raised doubt about whether adopting green practices such as green supply chain practices benefit the companies since it requires capital-intensive investment such as investment in new expensive technology. Combining the global trend and results from previous studies, this study examines the role of supply chain integration on firm performance through lean manufacturing, green supply chain management, and risk management. The novelty of this study is the new research model, which, to the best knowledge of authors, does not exist. In addition, this study is performed on the manufacturing industry in East Java Indonesia, which has never been performed before. This research topic raised four research problems: First, does supply chain integration affect lean manufacturing, green supply chain management, and risk management? Second, whether manufacturing affects green supply chain management, risk management, and firm performance. Third, whether green supply chain management affects risk management and firm performance. Finally, whether risk management affects firm performance.

2. Literature review

2.1. Supply Chain Integration

The company strives to increase competitiveness by integrating the supply chain to increase innovation capabilities (Freije et al., 2022; Siagian et al., 2022a). Supply chain integration consists of internal integration, supplier integration, and customer integration that can be integrated with enterprise resources planning with a single database (Tarigan & Siagian, 2021). Companies can build cooperation with external partners to generate higher efficiency and effectiveness as a collaboration strategy (Birasnav & Bienstock, 2019). Communication built by companies with external partners requires a long-time agreement to coordinate and collaborate (Dhaigude et al., 2020). Companies with external partners should build intensive communication to synchronize with external partners (Yuan et al., 2022). Real-time coordination and information are essential in integrating the supply chain (Fan et al., 2017; Riley et al., 2016; Jajja et al., 2018). Internal integration with suppliers is called supplier integration, while with customers, it is called customer integration (Qiao & Zhao, 2023). Internal integration between cross-functional departments enables decision-making to be determined independently but in sync with the needs of other functions (Munir et al., 2020). Hence, the ability of manufacturing companies to determine external integration (supplier

and customer) impacts company efficiency and effectiveness (Yuan et al., 2022; Pirmanta et al., 2021). Integration is effective through an integrated and interconnected system using the same data to obtain real-time information and make the proper decision-making (Basana et al., 2024; Hartono et al., 2023). Therefore, the supply chain process decreases the company's waiting time, decreases inventory levels, and increases operational efficiency (Siagian et al., 2022b).

Supply chain integration is a form of cooperation between companies and partners in optimizing value to provide benefits for both parties (Jajja et al., 2018; Yuan et al., 2022; Qiao & Zhao, 2023). The indicators of supply chain integration are defined as companies involve partners in determining joint decisions (Munir et al., 2020; Yuan et al., 2022; Qiao & Zhao, 2023), firms involve partners in determining planning strategies (Freije et al., 2022; Chen et al., 2018; Yuan et al., 2022; Tarigan & Siagian, 2021), the company engages partners in product development (Freije et al., 2022; Chen et al., 2018; Qiao & Zhao, 2023; Munir et al., 2020), companies involve partners in solving operational problems (Qiao & Zhao, 2023; Chen et al., 2018; Yuan et al., 2022), companies working with partners are well connected (Yuan et al., 2022; Qiao & Zhao, 2023; Munir et al., 2020) and companies share adequate information with partners (Freije et al., 2022; Chen et al., 2018; Yuan et al., 2022; Qiao & Zhao, 2023; Munir et al., 2020).

2.2. Lean Manufacturing

Lean manufacturing is a strategic step companies take to create customer value by reducing and eliminating waste (Golan et al., 2020; Kosasih et al., 2023). Companies can increase the use and empowerment of their resources to create value for customers (Alemsan et al., 2022; Oliveira-Dias et al., 2023). Lean management in companies, especially in factories, reduces variability in producing quality products (Garcia-Buendia et al., 2021). The company is trying to fix itself from the internal side of the company to eliminate waste that occurs (Sunder & Prashar, 2024). Companies require and build sound cooperation with suppliers to deliver reliable raw materials according to company needs (Vanichchinchai, 2020). The company focuses on products needed by customers with environmentally friendly products (Huo et al., 2019). Companies understand that customers will not pay for activities that do not add value to quality improvement, cost reduction, and productivity improvement (Cherrafiet al., 2018). Lean manufacturing that companies establish by reducing product defects (Bubber et al., 2023), excessive inventory, and waiting times can result in improved performance (Kuo & Lin, 2020). Lean manufacturing involving partners is called lean supply chain management, which is defined as a collaboration formed in several businesses connected from upstream to downstream with reduced costs and waste to be efficient (Tortorella et al., 2017). Lean manufacturing is implemented practically in companies such as value stream mapping, kaizen, standardized work, just-in-time, and total productive maintenance (Farias et al., 2019; Baumer-Cardoso et al., 2020).

The company needs suggestions and improvements provided by the company's internal and external partners to increase value for customers and increase the company's competitiveness (Ruiz-Benitez et al., 2018; Siagian et al., 2022a). Research establishes the operational definition of lean manufacturing is a way for companies to generate added value economically by reducing and eliminating waste in manufacturing companies (Huang et al., 2023; Alemsan et al., 2022; Kosasih et al., 2023; Bubber et al., 2023). The measurement item used for lean manufacturing is companies implementing process control systems on an ongoing basis (Bubber et al., 2023; Farias et al., 2019), companies implementing process improvements on an ongoing basis (Sunder & Prashar, 2024; Huo et al., 2019), companies trying to run operational processes promptly (Bubber et al., 2023; Sunder & Prashar, 2024; Farias et al., 2019), the company has a good production process layout (Sunder & Prashar, 2024; Vanichchinchai, 2020), the company has implemented maintenance planning well (Sunder & Prashar, 2024; Bubber et al., 2023; Farias et al., 2019) and the company has implemented quality planning well (Bubber et al., 2023; Vanichchinchai, 2020; Noviasuti et al., 2024).

2.3. Green Supply Chain Management

Green supply chain management (GSCM) is an approach companies use to involve external and internal partners to focus on maintaining a sustainable environment to provide sustainable performance (Karmaker et al., 2023). Businesses have committed to determining appropriate strategic steps to build environmental awareness (Kosasih et al., 2023) and improve economic sustainability (Basuki et al., 2023). Companies are under pressure from the community and local government to implement environmentally friendly activities (Tarigan et al., 2020). The community also always voices its opinions so that business activities and operations can be environmentally friendly (Novitasari & Tarigan, 2022). The company adapts to environmental friendliness by adopting eco-design, green purchasing, and green manufacturing so that the company's business activities can consider environmental impacts sustainably (Wungkana et al., 2023; Basana et al., 2022a). Climate change encourages companies to implement green supply chains (Setiawan et al., 2023). The company has integrated environmentally friendly practices from suppliers, internal processes, finished products, and customer delivery processes (Cherrafi et al., 2018). GSCM includes eco-friendly purchasing, manufacturing, material handling, distribution, and marketing practices to reduce the generated waste. Eco-friendly practices implemented by companies can provide cost reduction and efficiency (Siagian et al., 2023). GSCM contributes to the environment by using materials and products that can be recycled and disposed of safely. The company implements GSCM by actively involving suppliers and providing socialization to customers to use environmentally friendly products (Hartono et al., 2023). In the study, the operational definition of green supply chain management is the company's ability to build relationships with partners to be able to integrate environmental concepts into

the supply chain flow, starting from material selection, manufacturing processes, delivery of final products to customers in the company (Cherrafi et al., 2018). The measurement items used in GSCM are companies prioritizing suppliers who care about the environment (Setiawan et al., 2023), companies buying environmentally friendly raw materials (Setiawan et al., 2023), companies evaluating suppliers by applying environmental criteria (Setiawan et al., 2023; Hartono et al., 2023), the company carries out an environmentally friendly production process (Cherrafi et al., 2018; Siagian et al., 2023), and companies trying to reduce pollution (Cherrafi et al., 2018; Hartono et al., 2023).

2.4. Supply Chain Risk Management

Supply chain risk management (SCRM) is the company's ability to set a good strategy to anticipate losses that occur along the supply chain flow using information (Fan et al., 2017). Companies apply this method to anticipate and avoid losses in supply chain flows due to uncertainty (Qiao & Zhao, 2023). Moreover, the company should empower internal cross-functional and external partners (suppliers and customers) to identify and avoid losses that occur simultaneously or partially (Jajja et al., 2018). Companies should manage potential risks or minimize them so that there is no additional cost or time in providing products or services and the role of each component of the supply chain is balanced (Yuan & Li, 2022; Dubey et al., 2018). Risks that the supply side can cause include delays in the procurement of raw materials, delays in the production process, production schedule errors, and others (Sturm et al., 2022; Huma et al., 2020). SCRM can be said to be a company's ability to identify potential sources of risk and implement appropriate strategies to reduce supply chain vulnerabilities with the involvement and collaboration of supply chain partners (Kumar et al., 2018; Ali et al., 2023; Ahmed & Rashdi, 2021). The risk for companies and partners is not achieving a predetermined value criterion (Munir et al., 2020).

One of the risks companies faces is caused by suppliers' incapability to deliver raw materials to company demand (Huma et al., 2020). Therefore, suppliers find it challenging to provide raw materials that meet the criteria set by the company as one form of supply risk (Pham et al., 2023). This condition disrupts the flow of raw materials for the production process (Tse et al., 2018). The risks that companies avoid are generally related to financial losses (Qiao & Zhao, 2023). External risks the company faces are caused by external partners, such as key suppliers failing to provide needs affecting company operations, company operations experiencing product delivery disruptions, and companies to customers experiencing shipment disruptions (Jajja et al., 2018). SCRM in Sri Lankan companies becomes a corporate culture by mobilizing all internal components to seek and generate innovative ideas actively, the company's ability to produce products that quickly arrive in the market and encourage employees to be able to share knowledge about risk management (Abeysekara et al., 2019).

Companies having difficulty understanding specific customer requests will not be able to provide products required by customers (Ali et al., 2023). Hence, the company needs to coordinate with suppliers and customers to reduce the risk (Brusset & Teller, 2017; Zhu et al., 2017). Supply chain risk management is measured using operational indicators as a company's ability to identify potential sources of risk by implementing appropriate strategies in reducing vulnerabilities in supply chain flows by involving external partners (Ali et al., 2023; Qiao & Zhao, 2023; Jajja et al., 2018). The measurement item set for supply chain risk management is that companies have a system for detecting operational process risks (Qiao & Zhao, 2023; Brusset & Teller, 2017; Munir et al., 2020; Ali et al., 2023; Shou et al., 2018), companies have emergency procedures in dealing with changes in customer orders (Riley et al., 2016; Qiao & Zhao, 2023; Ali et al., 2023), companies have flexible material ordering systems (Brusset & Teller, 2017), companies have flexible payment systems as needed (Qiao & Zhao, 2023; Yuan & Li, 2022; Shou et al., 2018) and companies involve internal components in coping with emergency events (Riley et al., 2016; Brusset & Teller, 2017; Munir et al., 2020; Ali et al., 2023).

2.5. Firm Performance

Company performance is the result achieved by the company in a certain period determined by the company and mutually agreed upon by all stakeholders (Tarigan, 2018). Company performance can also be determined by comparing it with the performance of competing companies to determine the company's current position (Chen et al., 2018). The company's performance is determined by the efficient use of resources in producing products based on customer demand. Sustainable company performance is achieved by considering no dimensions, namely social performance, economic performance, and environmental performance (Kosasih et al., 2023). The company's achievement in producing quality and quantity of products has been determined by its operational performance. Company performance can be described by the level of achievement of the implementation of an activity or process in realizing the results and targets that have been set related to the achievement of flexibility performance, design performance, deliver performance, and agility performance (Jajja et al., 2018). Companies can measure the achievement of goals set in a certain period (Basana et al., 2024). The company's performance can be seen from operational performance related to capital, technology, and raw materials to achieve goals. The performance produced by the company does not stand alone but depends on external partners to support the company's operations (Siagian et al., 2022b). The continuity of the company's operational processes can produce optimal output and provide profits (Siagian et al., 2021). Tarigan's research (2018) sets indicators for company performance in small and medium enterprises, such as the ability to fulfill customer orders, product delivery speed, flexibility, and flexibility in changing product volume quantity. Chen et al. (2018) stated that sales, market share, and profit growth determine business performance. The measurement item set for firm performance is that the company produces adequate production volume (Tarigan, 2018; Munir et al., 2020; Shou et al., 2018;

Hartono et al., 2023), the company produces quality products (Tarigan, 2018; Munir et al., 2020; Siagian et al., 2021), companies produce high productivity above the average of serjeants companies (Chen et al., 2018; Siagian & Tarigaan, 2021), the company has the flexibility of product delivery according to customer needs (Jajja et al., 2018; Munir et al., 2020; Shou et al., 2018; Siagian & Tarigaan, 2021), the company provides a good response to customers (Munir et al., 2020; Hartono et al., 2023) and companies can meet consumer demand (Munir et al., 2020; Siagian & Tarigaan, 2021).

2.6. The Relationship Between Research Concepts

2.6.1. The relationship between supply chain integration and lean manufacturing

Using the right technology for company operations can impact supply chain integration to generate added value and improve company performance (Birasnav & Bienstock, 2019). The integration formed in the company is determined by developing a lean supply chain by reducing waste from upstream to downstream in providing products, services, and information to meet customer needs (Golan et al., 2020). The coordination formed by the company with partners can impact lean practice to increase the resilience of healthcare companies (Alemsan et al., 2022). Lean manufacture produced by companies requires components and integration in the supply chain to reduce non-value added (Ruiz-Benítez et al., 2018). Using technology 4.0 to integrate the supply chain by implementing big data analytics, the Internet of things, and cloud computing affects the lean supply chain with long-term planning and inventory control (Oliveira-Dias et al., 2023). Supplier and customer coordination can impact lean manufacturing by improving the company's production, purchasing, distribution, and facilities (Vanichchinchai, 2020). Supply chain integration with information technology capability, described as information systems are integrated to enable rapid change and compatibility, has an impact on lean manufacturing with better implementation of continuous improvement, implementation of 5S, total productive maintenance, and adoption of kanban systems (Siagian & Tarigan, 2021).

H₁: *Supply chain integration impacts increasing the adoption of lean manufacturing.*

2.6.2. The relationship between supply chain integration and green supply chain management

Process integration can impact the green supply chain that focuses on reducing impactful products and pollution (Huang et al., 2023). By establishing mechanisms that allow sustainable product flow, lean production in companies impacts the green supply chain by improving product quality (Bubber et al., 2023). Implementing environmentally friendly has been carried out with the green hotel program requires strong coordination and collaboration by running internal integration and external integration, namely upstream / downstream integration (Basana et al., 2022b). Supplier and customer integration can impact green supply chain practices by running green purchasing and manufacturing (Siagian et al., 2021; Basana et al., 2022a). ERP technology that allows companies to integrate with external partners has an impact on improving practicing green supply chain management (Santoso et al., 2022). Supply chain integration provides an integrated system between internal stakeholders, and sharing production planning influences improving green supply chain management (Setiawan et al., 2023)

H₂: *Supply chain integration influences on improving green supply chain management.*

2.6.3. The relationship between supply chain integration and supply chain risk management

Supply chain integration between companies and external partners can improve supply chain risk management to reduce financial risks (Qiao & Zhao, 2023). Supply chain integration consists of internal supply chain integration with measurements in inventory data integration, data integration with cross-function, and real-time integration. Cross-function impacts firm performance by increasing order fulfillment and delivery flexibility (Pirmanta et al., 2021). The company's ability to manage supply chain risk can positively impact supply chain supplier and customer integration but negatively impact internal integration (Jajja et al., 2018). Companies need to build alignment in the supply chain by integrating it to describe their respective roles and determining balanced risks, costs, and profits (Dubey et al., 2018). Companies need to manage the risks caused by customers and suppliers. Sturm et al. (2022) stated that managing risks that occur in supply chain integration from the supply side with robustness as a form of proactive and resilience as a form of reactive, while from the demand side, flexibility is needed in the form of proactive and agility in the form of reactive. Coordination with external partners can allow managers to identify risks to reduce costs (Brusset & Teller, 2017). Internal integration uses real-time data between departments to allow strong coordination so that operational continuity can be maintained without the risk of disruption (Munir et al., 2020; Fan et al., 2017). Internal integration can impact warning capacity with procedures that show threats and have a warning system so employees can understand quickly (Riley et al., 2016). Ali et al. (2023) stated that companies could reduce risks by building integration internally and externally to reduce risks caused by supply, production, and demand. Supplier integration that is formed can reduce risks in company procurement and provide materials on time and as needed (Huma et al., 2020). Supply chain risk in companies with information sharing and analysis can be well determined by external partners (Yuan & Li, 2022). Supply chain integration correlates with supply chain risk in anticipating uncertainty in suppliers, demand, and company operations (Zhu et al., 2017). Digital supply chains that allow companies to integrate internally and externally

influence supply chain risk in eliminating disruptions to the supply side, demand side, and product circulation (Song et al., 2024).

H₃: *Supply chain integration influences on improving supply chain risk management.*

2.6.4. The relationship between lean manufacturing and green supply chain management

The company's ability to manage production activities and processes by reducing product waste as lean green can impact green practices in small businesses with assets of US\$ 3205.51 to \$ 32,055.14 (Kosasih et al., 2023). A lean supply chain applied together with a green supply chain can benefit companies by producing economic performance (Huo et al., 2019). The company strives to eliminate excessive activities to produce environmentally friendly products by reducing waste and environmental pollution (Huang et al., 2023). Lean manufacturing applied to reduce waste with a just-in-time, set-up-time reduction approach impacts green supply chain performance by increasing integration and collaboration through green practices such as waste management, Eco-design, and life cycle assessment (Cherrafi et al., 2018). Lean manufacturing is related to energy consumption, producing products with high productivity and reducing waste (Farias et al., 2019). Green practices represent lean manufacturing in efficiently using materials, energy, and water (Baumer-Cardoso et al., 2020).

H₄: *Lean manufacturing in companies impacts improving green supply chain management.*

2.6.5. The relationship between lean manufacturing and supply chain risk management

The company's ability to maintain a practical role in maintaining the company's internal role in improving internal coordination can reduce production risk with a shortage of skilled workforce, high variability in production quality, high variability in production quantity, and high variability in production time (Qiao & Zhao, 2023). Disruptions in the company's supply and internal functions can affect operations that are not on time, resulting in non-value added for customers due to delivery delays, which become company losses (Jajja et al., 2018). The company's ability to condition production flexibility to improve lean by reducing inventory stock and employee strikes (Kumar et al., 2018). Lean supply chain strategy impacts supply chain robustness by mitigating disruptions and effectively managing supply chain risk (Ahmed & Rashdi, 2021).

H₅: *Lean manufacturing in companies impacts supply chain risk management.*

2.6.6. The Relationship between Lean Manufacturing and Firm Performance

Lean practices set by small business companies by reducing waste in each production activity can have an impact of 0.332 on improving sustainable performance (Kosasih et al., 2023). The lean supply chain produced in the company can impact sustainable performance (economic, social, and environmental) in 171 manufacturing companies (Huo et al., 2019). Lean manufacturing practice plays a role in encouraging the resilience of the company in order to be able to eliminate non-value added to have an impact on improving supply chain performance (Ruiz-Benítez et al., 2018). Lean management is implemented as a strategy for businesses to eliminate waste and reduce variability in the factory to improve performance (Garcia-Buendia et al., 2021). Lean management in 89 Brazilian companies impacts supply chain performance with increased delivery service levels and decreased costs with supply and raw materials (Tortorella et al., 2017). Lean practices implemented in companies in the form of just-in-time, total preventive maintenance, total quality management, and human resources management affect operational performance by increasing productivity and delivery of services (Sunder & Prashar, 2024). Lean supply chain applied to companies by running tools to eliminate waste, inventory control, and long-term planning affects improving operational performance with increased inventory turnover, on-time delivery performance, and fast delivery (Oliveira-Dias et al., 2023; Tarigan & Siagian, 2021). Lean manufacturing in companies influences operational performance with increased new product development and productivity (Siagian & Tarigaan, 2021). Lean manufacturing with just-in-time, zero defects, kanban, and cross-functional teams impacts innovation performance (Möldner et al., 2020).

H₆: *Lean manufacturing in companies has an impact on firm performance.*

2.6.7. The relationship between green supply chain management and supply chain risk management

Automation in manufacturing companies to improve quality and reduce dependence on labor can reduce the risk of environmentally friendly product quality (Kumar et al., 2018). An uncertain environment determined by disease and natural disasters, political and economic environment items is a moderating variable between digital supply chain and supply disruption risk, production disruption risk, demand disruption risk, and circulation disruption risk (Song et al., 2024). A good relationship is formed between companies and suppliers in supplier involvement by providing much input in the new product development process, which impacts increasing risk sharing related to problems that arise in the supply chain (Tse et al., 2018). Risk assessment practices in companies do not impact environmental supply chain aspects (Miemczyk & Luzzini, 2024). Green innovation has an impact on improving firm performance (Novitasari & Tarigan, 2022; Siagian et al., 2022a).

Environmentally friendly products produced by companies by involving members in the green supply chain are determined by risk-sharing and cost-sharing, which are determined by balanced coefficients (Wang et al., 2024).

H7: *Green supply chain management affects supply chain risk management.*

2.6.8. The relationship between green supply chain management and firm performance

Green practices set in small business companies can impact sustainable economic performance (Kosasih et al., 2023). Green supply chain management produced by the company has an impact on improving sustainable performance (economic, social, and environmental) in 171 manufacturing companies (Huo et al., 2019). Green supply chain practices in garment manufacturing companies in Bangladesh have an impact on improving sustainable performance (Karmaker et al., 2023). Green manufacturing in manufacturing companies can improve operational performance by increasing product quality and accuracy in delivery (Siagian et al., 2023). Environmental supply chain aspects are unrelated to risk assessment practice and performance but impact the triple bottom line (Miemczyk & Luzzini, 2024). Green hotel purchasing impacts green performance with less waste and reduced energy costs (Tarigan et al., 2020). Green purchasing and green production with a green information system can improve manufacturing performance (Wungkana et al., 2023; Basana et al., 2022a). Green supply chain management formed from government regulation, green manufacturing, and green purchasing can impact firm performance by increasing product quality and reducing production costs (Siagian et al., 2021). Green supply chain adoption with companies involved externally in implementing environmentally friendly and reliable green technology can improve firm performance (Hartono et al., 2023).

H8: *Green supply chain management affects firm performance.*

2.6.9. The relationship between supply chain risk management and firm performance

Supply chain risk caused by integration with company suppliers has a stronger influence than customer integration in determining agility performance (Jajja et al., 2018). Companies strive to identify internal and external manufacturing risks to produce products or services at the right time, which will impact company profitability and business performance (Kumar et al., 2018). Supply chain risk management in companies that prevent operation risk and detect operation risk impacts business performance by increasing flexibility, quality, delivery, and operational performance (Munir et al., 2020). The company's supply chain risk management can impact firm performance (Huma et al., 2020). Supply chain risk information analysis and the company's ability to assess processes and identify potential risks impact supply chain finance performance with increased loan volume and more flexible payments (Yuan & Li, 2022). Companies can share risks, costs, and rewards to improve operational performance (Zhu et al., 2017). The supply chain risk-sharing inner mechanism impacts operational performance (Fan et al., 2017). Preventing, detecting, responding, and recovering operation risk as a form of supply chain risk management can impact business performance, namely financial, operational flexibility, and operational efficiency (Shou et al., 2018). The supply chain risk management culture in Sri Lankan companies, which is illustrated by the policies used by the company in training employees to solve problems creatively by sharing skills and knowledge about risk management, has an impact on firm performance by increasing market share growth and products command a significant share of the market (Abeysekara et al., 2019).

H9: *Supply chain risk management affects firm performance.*

Based on the explanation above, it can be described by the following concept (Fig. 1).

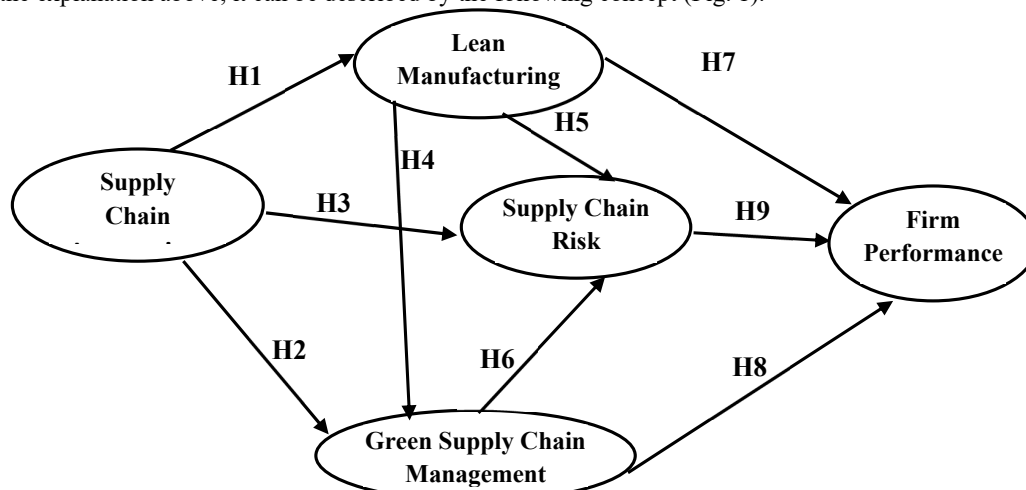


Fig. 1. The research conceptual framework

3. The research methods and goodness of fit

This research is quantitative, so it uses instruments or tools in the form of questionnaires that are organized and structured so that respondents can fill in the information correctly. Researchers chose the questionnaire because it is the most effective and efficient tool for processing numerical data. This study used data collection with a Likert scale (1= strongly disagree up to 5= strongly agree). Data collection is also carried out online, namely through Google Forms, which is distributed to respondents. The population taken is a company engaged in manufacturing located in East Java. Researchers found several companies that apply supply chain integration with information technology and lean manufacturing. Research determines the sample by having set criteria. The sample determined is a manufacturing company that has obtained ISO 14001 related to the environment; respondents with at least a staff position who have worked for more than 2 years and are permanent employees. This research is quantitative research, where the type of data used is data that can be converted into numerical form. Data collection is carried out using questionnaires with questions and statements that must be chosen by one of the respondents according to the circumstances in medium and large-sized companies. The total number of manufacturing companies that can be collected is 93 respondents using questionnaires through Google Forms.

The results of the questionnaires in the study were distributed to industry practitioners with sex characteristics consisting of 45 men (48%) and 48 women (52%). The characteristics of the length of work for respondents with work experience between 2 years to 3 years amounted to 34 respondents (37%), 4 years to 6 years amounted to 29 respondents (31%), 7 years to 10 years amounted to 11 respondents (12%) and the rest more than 10 years amounted to 19 people (20%). The characteristics of respondents based on the current position in the company were obtained with senior staff totaling 46 respondents (49%), supervisors totaling 27 respondents (29%), manager level totaling 17 respondents (18%), and top management level (Director/CEO/COO/CFO) totaling 4 respondents (4%). The measurement items assigned to the five variables: supply chain integration, lean manufacturing, green supply chain management, supply chain risk management, and firm performance, are described in Table 1.

Table 1
Measurement Goodness of Fit Penelitian

Measurement Items	Mean	Loading Factor	Reliability	Cronbach Alpha
Supply Chain Integration	3.724		0.898	0.895
The company involves partners in determining joint decisions (SCI1)	3.5914	0.818		
The company involves partners in determining the planning strategy (SCI2)	3.8387	0.893		
Company engaging product development partner (SCI3)	3.7527	0.774		
The company engages partners in resolving operational issues (SCI4)	3.3763	0.768		
The company works with partners is well connected (SCI5)	3.957	0.784		
Company sharing information with partners (SCI6)	3.828	0.818		
Lean Manufacturing	3.8746		0.886	0.878
The company implements a continuous process control system (LM1)	3.8602	0.795		
The company implements continuous process improvements (LM2)	3.871	0.739		
The company strives to carry out operational processes in a timely manner (LM3)	3.828	0.746		
The company has a good production layout (LM4)	3.7742	0.765		
The company has implemented a good maintenance plan (LM5)	3.9032	0.818		
The company has implemented quality planning well (LM6)	4.0108	0.862		
Green Supply Chain Management	3.7333		0.904	0.904
The company prioritizes suppliers who care about the environment (GSCM1)	3.6989	0.853		
The company purchases environmentally friendly raw materials (GSCM2)	3.7527	0.874		
The company evaluates suppliers by applying environmental criteria (GSCM3)	3.6344	0.881		
The company carries out an environmentally friendly production process (GSCM4)	3.7419	0.866		
Companies trying to reduce pollution (GSCM5)	3.8387	0.773		
Supply Chain Risk Management	3.7269		0.806	0.803
The company has a system in detecting operational process risk (SCRM1)	3.7849	0.658		
The company has emergency procedures in place to cope with changes in customer	3.7204	0.816		
The company has a flexible material ordering system (SCRM3)	3.7312	0.696		
The company has a flexible payment system as needed (SCRM4)	3.7097	0.736		
The company involves internal components in addressing emergency events (SCRM5)	3.6882	0.827		
Firm Performance	4.0717		0.904	0.9
The company produces adequate production volumes (FP1)	3.9032	0.735		
The company produces quality products (FP2)	4.2366	0.881		
The company produces productivity above the average of sejesnis companies (FP3)	3.8065	0.781		
The company has the flexibility of product delivery as per customer requirements (FP4)	4.0968	0.816		
The company has an excellent response to customers (FP5)	4.2151	0.812		
The company is able to meet consumer demand (FP6)	4.172	0.872		

Based on the results of Table 2, it was found that the outer model test for validity shown by the loading factor value has been above 0.50 so it is said to be valid, while for reliability tests for all variables shown by reliability and Cronbach Alpha is greater than 0.700 so it is said to be reliable. These results show that it can proceed to the next process, namely testing the inner model.

4. Analysis and Discussion

The results of inner model testing in answering research hypotheses are shown in Table 2 and Fig. 2.

Table 2
The Hypothesis Results

Direct Path Coefficients	Original sample	T statistics	P values	Remarks
Supp. Chain Integration → Lean Manufacturing (H1)	0.684	10.262	0.000	Support
Supp. Chain Integration → Green Supp. Chain Manag. (H2)	0.451	4.910	0.000	Support
Supp. Chain Integration → Supp. Chain Risk Manag. (H3)	0.333	4.429	0.000	Support
Lean Manufacturing → Green Supp. Chain Manag. (H4)	0.477	5.726	0.000	Support
Lean Manufacturing → Supp. Chain Risk Manag. (H5)	0.206	2.342	0.019	Support
Green Supp. Chain Manag. → Supp. Chain Risk Manag. (H6)	0.416	4.792	0.000	Support
Lean Manufacturing → Firm Performance (H7)	0.370	3.321	0.001	Support
Green Supp. Chain Manag. → Firm Performance (H8)	0.189	1.381	0.167	Not Support
Supp. Chain Risk Manag. → Firm Performance (H9)	0.354	2.784	0.005	Support

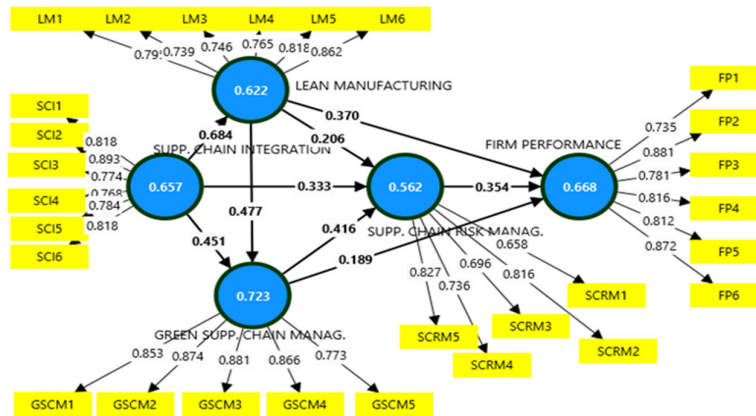


Fig. 2. Analysis results using the smartPLS

Based on the test results indicated in Table 2 and the research model in Fig. 2, eight of nine hypotheses are empirically supported, and one hypothesis (H8) is not supported. Supply chain integration affects lean manufacturing (H1) with a t-statistics value of 10.262 (>1.96). Supply chain integration, indicated by the company's ability to involve partners in solving operational problems and determining planning strategies enables the company to adopt lean manufacturing. The lean manufacturing implementation process carries out process improvements on an ongoing basis with an excellent production layout. Besides, the companies identify production process traffic and control processes using Kanban. The results confirm the results of previous research (Birasnav & Bienstock, 2019; Golan et al., 2020; Alesman et al., 2022; Ruiz-Benítez et al., 2018; Oliveira-Dias et al., 2023; Vanichchinchai, 2020; Siagian & Tarigan, 2021).

Further, supply chain integration affects green supply chain management (H2) with a t-statistics magnitude of 4.910 (>1.96). Supply chain integration is determined by the involvement of partners in product planning and strategies to improve green supply chain management. The company can implement green supply chain management through green practices to purchase environmentally friendly raw materials from suppliers that apply environmental criteria. This result supports the past research, which states that supply chain integration influences improving green supply chain management practices (Huang et al., 2023; Bubber et al., 2023; Basana et al., 2022b; Siagian et al., 2021; Santoso et al., 2022; Setiawan et al., 2023). The third hypothesis (H3), supply chain integration affects supply chain risk management, is supported by a t-statistics magnitude of 4,429 (>1.96). Companies that have built internal and external integration, as described by the involvement of partners in solving operational problems, making joint decisions, and determining planning strategies, impact supply chain risk management through the possibility of detecting operational process risks and flexible material ordering systems. The results confirm the results of research that state supply chain integration affects good supply chain management control (Qiao & Zhao, 2023; Pirmanta et al., 2021; Jajja et al., 2018; Dubey et al., 2018; Sturm et al., 2022; Brusset & Teller, 2017; Munir et al., 2020; Fan et al., 2017; Riley et al., 2016; Huma et al., 2020; Yuan & Li, 2022; Song et al., 2024). Moreover, implementing lean manufacturing improves green supply chain management (H4) and is accepted with a t-statistics value of 5,726 (>1.96). Lean manufacturing, indicated by the ability to implement maintenance and quality planning well, impacts green supply chain management to enhance environmentally friendly production process and reducing air pollution. The results of the study have confirmed the past results, which states that lean manufacturing in companies has an impact on improving green supply chain management adequately (Kosasih et al., 2023; Huo et al., 2019; Huang et al., 2023; Cherrafi et al., 2018; Farias et al., 2019; Baumer-Cardoso et al., 2020). The fifth hypothesis, which determined that lean manufacturing affects supply chain risk management, was obtained with a t-statistics value of 2.342 (>1.96), so it is declared an acceptable hypothesis. The results showed that lean

manufacturing in companies can improve supply chain risk management by implementing a continuous process control system and continuous process improvements. The implementation of the system can detect operational process risks and have emergency procedures to overcome changes in customer orders. The study's results have supported previous studies that revealed lean manufacturing affects supply chain risk management (Qiao & Zhao, 2023; Jajja et al., 2018; Kumar et al., 2018; Ahmed & Rashdi, 2021). Lean management in manufacturing companies affects firm performance as the sixth hypothesis, with a t-statistics value of 4,792 (>1.96) is considered an acceptable hypothesis. Lean manufacturing show the company's ability to implement continuous process improvements and the application of process control systems on an ongoing basis which impact firm performance by increasing production volume and adequate product quality. The results support the results of research which states that lean management practice has an influence on improving firm performance (Kosasih et al., 2023; Huo et al., 2019; Ruiz-Benítez et al., 2018; Garcia-Buendia et al., 2021; Tortorella et al., 2017; Sunder & Prashar, 2024; Oliveira-Dias et al., 2023; Siagian & Tarigaan, 2021; Möldner et al., 2020).

The seventh hypothesis, that green supply chain management affects supply chain risk management, with t-statistics 3.321 (>1.96), was declared an acceptable hypothesis. Green supply chain management determined by buying environmentally friendly raw materials, prioritizing suppliers who care about the environment, and environmentally friendly production processes can improve supply chain risk management. This condition creates a system for detecting operational process risks and involving internal components such as employees, infrastructure, and capital in overcoming emergency events. This study supports the results of research that stat that green supply chain management affects supply chain risk management (Kumar et al., 2018; Song et al., 2024; Tse et al., 2018; Novitasari & Tarigan, 2022; Wang et al., 2024), and in contrast to Miemczyk & Luzzini (2024) who stated that green supply chain management does not have a direct impact on supply chain risk management. However, the eighth hypothesis (H8) that green supply chain management impacts firm performance is not supported on this study with t-statistics 1,381 (<1.96). Green supply chain management that is applied practically to companies with environmentally friendly production and procurement process activities cannot directly impact firm performance. The results of this study are different from the results of research which states that green supply chain management has an impact on firm performance (Kosasih et al., 2023; Huo et al., 2019; Karmaker et al., 2023; Siagian et al., 2023; Tarigan et al., 2020; Wungkana et al., 2023; Siagian et al., 2021; Hartono et al., 2023), and in accordance with Miemczyk & Luzzini's (2024) research which states that green supply chains related to environmental aspects are not directly correlated with performance but to the triple bottom line. It may be since the Indonesian manufacturing company are not yet seriously adopting the green practice due to uncertainty of the benefit in the investment of green production technology. The ninth hypothesis (H9), which states that supply chain risk management affects firm performance with t-statistics 2,784 (>1.96), is considered acceptable. Supply chain risk management with an overview of having a system for detecting operational process risks, having emergency procedures in overcoming changes in customer orders, and involving internal components in overcoming emergency events can have an impact on firm performance by increasing the ability to produce production volumes, quality products, good responses to customers and meet consumer demand. The results of this study support the results of research which state that supply chain risk management affects firm performance (Kumar et al., 2018; Munir et al., 2020; Huma et al., 2020; Yuan & Li, 2022; Zhu et al., 2017; Fan et al., 2017; Shou et al., 2018).

These results show that manufacturing companies in East Java have implemented information technology that allows it to be integrated internally and externally as a form of supply chain integration. This condition shows that supply chain integration in companies by involving partners in determining planning strategies, product development, and solving operational problems can impact lean manufacturing practices, green supply chain management, and risk management. Lean manufacturing that has been adopted by implementing a continuous process control system and continuous process improvements can impact green supply chain management, risk management, and firm performance. Green supply chain management is determined by purchasing environmentally friendly raw materials and evaluating suppliers by applying environmental criteria and environmentally friendly production processes, which has an impact on improving supply chain risk management and firm performance. The company's ability to detect operational process risks, emergency procedures in overcoming changes in customer orders, material ordering systems, and flexible payments have an impact on firm performance with an adequate increase in production volume, quality products, productivity above the average of the company and able to meet consumer demand.

5. Conclusion

This study has examined the influence of supply chain integration on firm performance through lean manufacturing, green supply chain management, and risk management. The results of the study are withdrawn as follows. The company's ability to build supply chain integration by involving partners in making joint decisions, determining planning strategies, and product development has an impact on improving lean manufacturing by establishing a continuous process control system and continuous process improvement. Supply chain integration impacts green supply chain management by increasing the use of raw materials that are friendly to the environment and reducing pollution. Supply chain integration to supply chain risk management to form a system for detecting operational process risks and emergency procedures to overcome adequate customer order changes. Lean manufacturing impacts green supply chain management, risk management, and firm performance. Green supply chain management in companies impacts improving supply chain risk management and indirectly on firm performance. Green supply chain management did not directly affect the firm's performance. Supply chain risk

management impacts firm performance by increasing adequate production volumes, quality products, productivity above the average of other companies, and ability to meet consumer demand. The study's results contribute to practitioners by increasing investment in information technology systems to strengthen supply chain integration. Contribution to top management to maintain a commitment to adopting lean manufacturing and green supply chain management with ISO 14000. Theoretical contribution by increasing literacy on resources-based view theory in building competitiveness with supply chain risk management and green supply chain.

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