The Mediation Role of Flexibility on the Relationship Between Sustainable Supply Chain and Operational Performance: US Manufacturing Industry

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Abstract

This paper investigates the interaction between flexibility practices, sustainability practices, sustainability performance, and operational performance metrics of manufacturing companies. A survey of domestic automotive manufacturing companies in the United States (U.S.) was carried out with 101 responding facilities in a face-to-face interview from 101 different manufacturing plants (19 different Automotive manufacturing companies). The model-hypothesized relationships were tested through a partial least square structural equation model (SmartPLS). The paper provides insight into the positive mediating role/influence of flexible manufacturing systems practices on the relationship between sustainability, supply chain, and operational performance. Data indicate a significant correlation between flexibility and supply chain dimensions. The following research is one of few that investigates comprehensive flexibility, supply chain, and sustainability dimensions and interactions based on what is currently applied by the automotive industry in the U.S. The results indicate that flexibility practices implantation is critical for maximizing the outcomes of sustainability implementation in the US automotive facilities. The findings provide an important guide for practitioners and researchers implementing supply chain and sustainability dimensions in the manufacturing industry and the effect of flexibility dimensions implementation levels on such practices.

Keywords
Flexible Manufacturing Systems, Supply chain practices, Sustainability, operational performance metrics

1. Introduction

Driven by globalization, economic, political, and social uncertainties, and to stay competitive, manufacturers are forced to be creative and innovative. According to the IMD 2020 report on manufacturing competitiveness, increasing awareness by several international organizations on the issue of climate change led many companies to implement new philosophies such as flexibility and sustainable practices. Accordingly, many manufacturing organizations started to consider sustainability as an essential driver for survival (Bevilacqua et al. 2007). Sustainability is the ability to create long-term value while taking into consideration the social, economic, and ecological environment (Vinodh...
IMD (2020) discussed the need for more research into sustainability enablers and how other philosophies such as flexibility impact sustainability implementation.

Supply chain management has become a subject of increasing interest to academics, consultants, and managers (Christopher 1992; Hines 1995). Uncertainty is still present regarding the concept, categories, and dimensions of supply chain management (Morali and Searcy 2013). Despite the considerable interest demonstrated by scholars, there is a lack of agreement amongst researchers regarding the official definition of supply chain management (Saunders 1995; Newman et al. 1993; Bagozzi et al. 1991). The term supply chain is not only used in logistics and control of materials activities. Some academics used the supply chain to describe the strategic and inter-organizational issues (Cox and Spencer 1998) while others used it to describe the relationship between the company and its suppliers (Lavington 1921, Sako 1992; Lamming 1993; Hines 1995). Authors such as Nath and Agrawal (2020) indicated the need for more empirical research on the relationship between flexibility and supply chain in the manufacturing industry.

Several studies explored flexibility, supply chain, and sustainability practices (Marshall et al., 2015). After an extensive review of the literature, which includes reputable and high impact factor journals, none of the previous studies have examined sustainability, flexibility, and supply chain at the same depth and breadth presented in this research. However, relevant reports and studies were very crucial for our study. Therefore, this paper aims to investigate the relationships between flexibility, supply chain, sustainability, and operational performance.

Accordingly, the following hypotheses are derived:

- **H1:** Flexibility practices have a positive effect on sustainability performance.
- **H2:** Flexibility practices have a positive effect on operational performance.
- **H3:** Sustainable supply chain practices have positive effects on operational performance.
- **H4:** Sustainable supply chain practices have positive effects on sustainability performance.
- **H5:** Flexibility practices mediate the relationships between sustainable supply chain practices and sustainability performance.
- **H6:** Flexibility practices mediate the relationships between sustainable supply chain practices and operational performance.
- **H7:** Sustainable supply chain practices have positive effects on flexibility practices.

The above hypothesis was part of a discussion that took place with some senior directors at the Big Three (General Motors, Chrysler, FiatChrysler) automotive industry in North America. The directors indicated that significant investment was made in implementing flexibility (Flexible manufacturing systems) and sustainability since the beginning of the 21st century. This investment varied and in-depth and breadth. They indicated that the manufacturing facility managers are not confident or clear on the benefits of such investment. They understand that the operational performance has improved significantly, the question is, what of those philosophies driving what metrics and what type of interaction is there between such philosophies constructs and or variables. After reviewing some of the literature results with directors interviewed, such as the work conducted by Geyi et al. (2020), EL-Khalil and Darwish (2019), Jadhav et al. (2019), Gunasekaran et al. (2019), Katiyar et al. (2018), Kaur et al. (2017), Ketokivi (2009), and Ganeshan et al. (2001), noted the following concerns:

1. The supply chain, flexibility, sustainability practices presented in this literature is limited to depth and breadth.
2. Operational performance measured in most cases does not focus on critical or metrics.
3. Agility implementation in most facilities started after 2017, and flexibility implementation result was never measured as part of the model presented in this research.
4. Flexibility is the foundation for agility, therefore measuring the impact of flexibility needs to be measured understood.
5. Director also pointed out several issues that literature needs to consider when conducting such research such as union, lean implementation, JIT centers (internal and external to manufacturing facilities), Kitting of parts, skilled and none skilled work, …etc.

Previous research in manufacturing noted similar concerns and recommended that future research should focus on such a model presented in this research (Geyi et al., 2020; Jadhav et al., 2019; Gunasekaran et al., 2019; Gunasekaran 1999a,b).
2. Literature Review

2.1 Flexible Manufacturing Systems (FMS)

The paramount modification induced by rapid globalization, fluctuation in customer demand, and advancements in technologies have elevated the competition level between organizations (Bengtsson and Olhager 2002). Accordingly, organizations from various countries started to implement flexibility tools to deal with uncertainties, improve productivity, and survive global competition (Boyle 2006; Anand and Ward 2009). Lavington (1921) defined flexibility as the ability to create systems that can adjust to changes. Authors such as Rosenhead (1972), Slack (2005), Sethi and Sethi (1990), Newmen et al. (1993), Correa (1994), Gupta and Buzacott (1996), defined flexibility as the ability of a system/process to adjust to changes with minimal or no impact to its final output. Vokurka and O’Leary (2000) developed a comprehensive list of fifteen FMS dimensions. El-Khalil and Darwish (2019) established three categories and focuses on the fifteen dimensions, as illustrated in Table 1.

Few empirical studies investigated the importance of flexibility in manufacturing and its impact on manufacturing performance (Gunasekaran 2019). Zhang et al. (2003) studied the effect of flexibility on operational performance. The study discussed the positive result achieved through implementing machines, material handling, and operational flexibility. Slack (2005) indicated that volume flexibility must be present in low variety and high uncertainty; it significantly enhances the organization's ability to deal with market and environment fluctuations. Delic and Eyers (2020), indicate that flexibility implementation is critical in achieving improvement in manufacturing performance. Implementing flexibility results in a higher level of customer satisfaction, quality, and productivity (Aprile et al. 2005). Gunasekaran (2019) illustrated the significance of implementing FMS in the supply chain due to its ability to minimize cost and eliminate uncertainties.

Yu et al. (2015) stated that flexibility reduced manufacturing time and cost and enhanced the organization’s ability to introduce new products and services. El-Khalil and Darwish (2019) studied the adoption level of flexibility in the U.S automotive industry. Their study indicated that implementing all flexibility tools/dimensions might not be efficient for organizations. Instead, specific flexibility dimensions must be implemented depending on the performance metric the organization is aiming to improve. He et al. (2016) studied the effect of utilizing robot and machine scheduling in an FMS. Their result stressed the importance of satisfying different customer demands (i.e. price and value). Mendes and Machado (2015) reported that employee’s skills are an important element in the process of implementing FMS. Two aspects of manufacturing flexibility were proposed by Yu et al. (2015): strategic manufacturing flexibility and operational manufacturing flexibility. Ketokivi (2009) studied the implementation level of flexibility in North America, Europe, and the Far East. The result shows that operational performance will show different levels of improvement even within the same industry due to the dynamic of the static aspect of the industry.

<table>
<thead>
<tr>
<th>Level</th>
<th>#</th>
<th>Flexibility Type</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Necessary flexibility Operational (focus)</td>
<td></td>
<td>Machine</td>
<td>Refers to the ability of the system to switch operation without requiring major effort</td>
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<tr>
<td></td>
<td></td>
<td>Material Handling</td>
<td>The ability to move different part types efficiently for proper positioning and processing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Operation</td>
<td>The ability of the part to be produced in different ways with alternative process plans</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Automation</td>
<td>The capability of the automation to perform different operation and or add operation</td>
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<tr>
<td></td>
<td></td>
<td>Labor</td>
<td>The ability to change number of workers, tasks performed by workers, and responsibility</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Process</td>
<td>Relates to the set of part types that the system can produce without major set-up</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Routing</td>
<td>The ability to produce a part by alternative routes</td>
</tr>
<tr>
<td>Sufficient flexibility Tactical (focus)</td>
<td></td>
<td>Product</td>
<td>The ease with which new parts can be added or substituted for the existing parts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>New Design</td>
<td>The ease by which the system produces a product with different shapes and/or dimensions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Delivery</td>
<td>The ease to transporting material to the manufacturing facility, as well as to operation within the facility</td>
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<tr>
<td></td>
<td></td>
<td>Volume</td>
<td>The ability to be operated profitably at different product overall output levels</td>
</tr>
<tr>
<td>Competitive flexibility Strategic (focus)</td>
<td></td>
<td>Expansion</td>
<td>The ease with which the capacity and capability can be increased when needed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Program</td>
<td>The ability of the system to run virtually untended for a long enough period</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Production</td>
<td>The universe of part types that the FMS can produce</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Market</td>
<td>The ease with which the manufacturing system can adapt to a changing market environment</td>
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</table>
According to Slack (2005), Dynamic flexibility and static flexibility are two aspects of flexibility. They are used for short term and long-term operations, respectively. Furthermore, Slack (2005), stated that response flexibility and range flexibility are assessed by their speed of responsiveness to change, and by the number of changes it can accommodate, respectively. Stockton and Bateman (1995), Brown et al. (1984), and Narain et al. (2000), identified thirteen types of flexibility. EL-Khalil and Darwish (2019) indicated that managers who implemented FMS at various manufacturing industries agreed that the most critical performance metrics are jobs per hour, lead-time, productivity, and quality. Wei et al. (2017), indicated that flexibility implementation is critical for achieving efficiency and productivity. Caprihan et al. (2013), Kaur et al. (2017), and Ghosh (2012) indicated that flexibility has a positive effect on quality. Johnzén et al. (2011) showed that flexibility has a positive effect on productivity. Swamidass and Newell (1987) stated that by applying both mix and volume flexibility, the organizational performance would be enhanced. According to EL-Khalil and Darwish (2019), previous work on FMS implementation in the manufacturing industry indicates the positive impact of flexibility on operational performance. The few empirical works on flexibility (FMS) implementation indicate a lack of in-depth and breadth when it comes to investigating FMS dimensions (Delic and Eyers 2020; Gunasekaran 2019).

2.2 Supply Chain practices and sustainability

Delivering services and products effectively and efficiently is a top priority for any organization that wants to compete in today’s global markets. This can be achieved by proper design and coordination of the supply and distribution network. Several authors tried to define supply chain management, as illustrated in Table 2. Delic and Eyers (2020), define supply chain management as an efficient and effective way of planning and controlling material that starts at the suppliers and ends with the customer.

Supply chain management covers a variety of areas such as supply network structure, supplier collaboration, and supplier relationships. Sengupta et al. (2006) indicate that in recent years one of the main focuses of supply chain management is to improve supply chain performance through addressing every aspect of supply chain practices. Due to globalization that intensified competition between organizations, many companies started to compete based on their supply chain practices breadth and depth (Sengupta et al. 2006). Croom et al. (2000) identified eleven components bodies of supply chain present in the literature—including logistics and transportation, purchasing and supply, networks, marketing, contingency theory, organizational behavior, best practices, strategic management, institutional sociology, economic development, and systems engineering. Croom et al. (2000) clustered the eleven components into six main areas; strategic management, relationships/partnerships, logistics, best practices, marketing, and organizational behavior.

The strategic manufacturing process (SMP) affects supply chain performance (Sengupta et al. 2006). The SMP role is critical to achieving an effective supply chain process (Geyi et al. 2020). Armistead and Mapes (1993) measured the strength of integration in the extent of shared ownership of master production schedules, use of job titles that span traditional functions, level of adherence to manufacturing plans, level of visibility and spread of information, and extent of integration of information systems as a part of SMP. According to Waller (1993), SMP has a direct effect on purchasing in the supply chain. Due to the competitive advantage that the company supplier can provide, purchasing became an important part of any organization (Narasimhan and Kim 2002). Xerox, for instance, has decreased material costs to its half by effectively managing the sourcing decisions (Bleil 1993). Moreover, Strategic manufacturing planning/role can affect the supply chain performance in terms of outsourcing (Frazier et al., 1988; Higginson and Bookbinder, 1990), supplier capability assessment and management (Lascelles & Dale 1990; Schonberger & Ansari 1984; Waller 1993), degree of manufacturing goal achievement (Skinner 1985).


In the traditional supply chain, the environmental and social impacts of the production process are not taken into consideration (Marshall et al. 2015). However, in the sustainable supply chain, the organization aims to improve the
social condition of different stakeholders of the supply chain and reduce the environmental impact (Sancha et al. 2016). Through the years, the implementation of supply chain sustainability has been defined under a set of standards like ISO 14001 and SA 8000 (Treacy et al. 2019). Several studies have examined the implementation of proactive sustainable product design within multi-layer supply chains (Grimm et al. 2014). Mohanty and Prakash (2014) studied the green supply chain management in India. While other studies examined investment recovery (Zhu et al. 2013, Zhu and Sarkis 2004) and sustainable procurement (Vachon and Klassen, 2006; Paulraj et al. 2017; Zhu et al. 2013; Morali and Searcy 2013) as sustainable practices.

### Table 2. Supply chain definitions by Author

<table>
<thead>
<tr>
<th>Authors</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jones and Riley (1985)</td>
<td>An integrative approach to dealing with the planning and control of the materials flow from suppliers to end-users.</td>
</tr>
<tr>
<td>Ellram (1991)</td>
<td>A network of firms interacting to deliver product or service to the end customer, linking flows from raw material supply to final delivery.</td>
</tr>
<tr>
<td>Christopher (1992)</td>
<td>Network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer.</td>
</tr>
<tr>
<td>Lee and Billington (1992)</td>
<td>Networks of manufacturing and distribution sites that procure raw materials, transform them into intermediate and finished products, and distribute the finished products to customers.</td>
</tr>
<tr>
<td>Berry et al. (1994)</td>
<td>Supply chain management aims at building trust, exchanging information on market needs, developing new products, and reducing the supplier base to a particular OEM (original equipment manufacturer) so as to release management resources for developing meaningful, long term relationship.</td>
</tr>
<tr>
<td>Saunders (1995)</td>
<td>External Chain is the total chain of exchange from original source of raw material, through the various firms involved in extracting and processing raw materials, manufacturing, assembling, distributing and retailing to ultimate end customers.</td>
</tr>
<tr>
<td>Kopczak (1997)</td>
<td>The set of entities, including suppliers, logistics services providers, manufacturers, distributors and resellers, through which materials, products and information flow.</td>
</tr>
<tr>
<td>Lee and Ng (1997)</td>
<td>A network of entities that starts with the suppliers' supplier and ends with the customers' custom the production and delivery of goods and services.</td>
</tr>
<tr>
<td>Tan et al. (1998)</td>
<td>Supply chain management encompasses materials/supply management from the supply of basic raw materials to final product (and possible recycling and re-use). Supply chain management focuses on how firms utilize their suppliers' processes, technology and capability to enhance competitive advantage. It is a management philosophy that extends traditional intra-enterprise activities by bringing trading partners together with the common goal of optimization and efficiency.</td>
</tr>
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</table>

The literature review conducted identified seven main constructs for supply chain performance (planning, sourcing, make, assembly, packaging, delivery and return) as illustrated in Appendix A. Some of which are divided into several subcomponents. For example planning performance is divided into order planning, tactical planning, and inventory strategy.

### 2.3 Sustainability Performance

Sustainability encompasses practices designed by organizations to reduce the environmental impact, improving financial growth, and improve the social welfare of all stakeholders. According to Katiyar et al. (2018), optimizing sustainability performance within any organization relies on the ability to address sustainability at every level including supplier (including sub-suppliers). The benefits of sustainability implementation improve quality, reduce cost, improve lead-time, and enhances the overall customer image and reputation (Chen et al. 2017). Sustainability performance is addressed in three dimensions, as illustrated in Table 3.
Table 3. Sustainability constructs and indicators

<table>
<thead>
<tr>
<th>Latent Variable</th>
<th>Manifest variable</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social</td>
<td>The firm has very good relations with the community and stakeholders</td>
<td>Paulraj et al. (2017); Jennings (2013); Krause et al. (2009); Chin et al. (2015); Sarkis et al. (2010); Klassen and Vereecke (2012)</td>
</tr>
<tr>
<td></td>
<td>Work in the firm is safe</td>
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<tr>
<td></td>
<td>Employee health and safety (Improvement)</td>
<td></td>
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<tr>
<td></td>
<td>Work environment (Improvement)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Improve the living quality of surrounding community</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The firm takes social welfare initiatives</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The firm complies with laws and standards</td>
<td></td>
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<tr>
<td></td>
<td>The firm highly respects human rights</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The firm has good working conditions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The firm treats suppliers fairly</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The firm ensures product safety</td>
<td></td>
</tr>
<tr>
<td>Environmental</td>
<td>Reduce CO2 emissions</td>
<td>Paulraj et al., 2017; Zhu et al., 2013; Wong et al., 2012; Esfahbodi et al., 2017; Blome et al. (2014)</td>
</tr>
<tr>
<td></td>
<td>Reduction of wastewater</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reduction of solid wastes</td>
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</tr>
<tr>
<td></td>
<td>Reduction of energy consumption</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decrease in production of toxic, hazardous, or harmful substances</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decrease in material usage</td>
<td></td>
</tr>
<tr>
<td>Economic</td>
<td>Improved compliance with environmental standards</td>
<td>Yusuf et al., 2013; 2014; Golicic and Smith (2013); Paulraj et al. (2017)</td>
</tr>
<tr>
<td></td>
<td>Improved market share</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Improved company image</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Improved company’s image in market place</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increase profitability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decreasing in material purchasing cost</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decrease in utility bills</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decrease in waste treatment fees</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decrease in waste discharge fees</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reduction of environmental accident cases</td>
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</tr>
<tr>
<td></td>
<td>Improved product quality</td>
<td></td>
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</tbody>
</table>

Several studies have demonstrated the importance of social sustainability (Walker et al. 2014). “Human Capital” and “Social Capital” are two types of social sustainability (Chen et al. 2017). Social capital is the ability to respect the interest of the society in which the company’s resources are allocated and improve the individual’s quality of life while reducing the environmental impact. Human capital includes employee commitment level, workers diversity and inclusions, integrity and equity in the working conditions, the safety of workers, and continuous development of employee skills (Carter and Rogers 2008).

Environmental sustainability concentrates on minimizing the utilization of natural resources (water, energy, materials, and atmosphere) to avoid degradation or depletion of natural resources and allow for long-term environmental quality (Paulraj et al. 2017). More importantly, the impact of economic and human activities on the origin of the resources through the entire process must be taken into consideration (Zhu et al. 2013). Environmental sustainability has several metrics such as water usage, water pollution, waste generation, greenhouse gas emissions, and energy consumption (Wong et al., 2012; Blome et al. 2014).

Economic performance focuses on increasing profitability and sales. Sarkis et al. (2011) stated that various studies indicated a positive relationship between sustainability and economic growth. Some of the metrics that have been improved are ROA, profit as a ratio of sales, company’s image, quality, and market share (Paulraj et al. 2017).

According to Katiyar et al. (2018) and Gunasekaran (2019), sustainability act as a mediator in the relationship between different aspects/philosophies of the organization such as supply chain and operational performance. Delic (2020), discusses the importance of implementing sustainability and the need for more empirical research that investigates the benefits of this implementation in the manufacturing industry. Sony (2018) proposed a sustainability model that guides and helps organizations to achieve organizational excellence.

2.4 Operational Performance Metrics

The operational performance objectives depend on the method the organization seeks to compete in and on the market conditions (Porter, 2004). Authors like Gehani (1995), Sainis et al. (2017), Hill et al. (2017), Gunasekaran (1998, 1999a, 1999b), (El-Khalil and Mezher 2020), and Sahin (2000) measured the firms' performance against a defined set of performance metrics such as cost, quality, productivity, delivery, and morale. Cost includes equipment, startup,
material, material, and labor. The company’s sales volume and pricing strategy depend on its cost position (Hart 1940; Hayes and Wheelwright, 1984). For example, a high-cost position might reduce the company’s sales volume. While a low-cost, position might increase the company’s sales volume. A low-cost position is preferred for a better value of money. The company's competitive edge depends on its products and service quality. Quality is measured through total productive maintenance (TPM), statistical process control (SPC), autonomation, kaizen, lean six sigma, and lean production system (i.e. standardization, 5 wastes, 7s). Process quality and service/product quality are two types of qualities. Product and service quality is the ability to conform to customers’ demands and expectations (Gunasekaran et al. 2019). While process quality is the ability to conform to a pre-defined set of criteria (Gunasekaran et al. 2019). Delivering products and services in the shortest time is the goal of every company (Yusuf et al. 2013, 2014). Customers might lose trust if the company fails to deliver on time. Shorter delivery periods lead to waste reduction, less inventory, and reduced operational costs (Gordon and Sohal 2001). Delivery is measured in cycle time, lead-time, queues, blockers, throughput, and work in progress (WIP). Productivity is the rate of output per unit of input (Sahin, 2000). Better productivity means improved efficiency. Productivity is measured through labor utilization, employee turnover rate, overall labor effectiveness, downtime, and sales growth. As for employee morale, it can be measured through loyalty, commitment, absenteeism, empowerment, motivation, and citizenship (Mat et al. 2017).

3. Conceptual model and hypothesis development

Investigating the concept of flexible manufacturing systems mediating or moderating the relationship between sustainable supply chain and operational performance metrics was developed based on literature review and practitioner's opinion from the Big Three (General Motors, Ford, FiatChrysler LLC) automotive manufacturing companies in North America. Several managers (at the Big Three) approved/suggested this model after a long discussion regarding the ability of their organization to efficiently and effectively adapt its resource base (i.e. dynamic capability). The proposed conceptual model is illustrated in Figure 1. The model latent variables-constructs manifest variables, and indicators are illustrated in Appendix B.

3.1 The impact of flexibility on operational performance metrics

In line with previous research conducted by Geyi et al. 2020; Aslam et al. 2018; Katiyar et al. 2018; and Eckstein et al. 2015, this paper's research proposed model is grounded in the dynamic capability view of the firm. The proposed model provides a manufacturing industry perspective of the relationships guiding the model dimensions/elements. The proposed model presents a guide for practitioners regarding the influence of the proposed dimensions on improving operational performance as well as the impact of sustainable supply chain and flexibility dimensions on each other. The depth and breadth (more dimensions /categories /elements) of the proposed model are unique in comparison with previous work conducted by authors such as Geyi et al. (2020) and Katiyar et al. (2018). This paper is the first that considered such a model in the manufacturing industry in North America. Geyi et al. (2020); Gunasekaran et al. (2019); Ciccullo et al. (2018), indicated a lack of empirical study testing the impact of flexible manufacturing systems on sustainable supply chain performance.
The flexible manufacturing systems philosophy is designed to create a manufacturing system that can adjust to system changes/problems with minimum impact on the output of the system (EL-Khalil and Darwish 2019). According to Boyle (2006), FMS requires information sharing between manufacturers and suppliers throughout the supply chain, supplier's involvement in every aspect of the manufacturing process, and supplier's input regarding improvement (material, logistics, Just in time, etc). Such requirements will positively influence sustainability. Collaboration between manufacturers and suppliers will result in a reduction of hazardous, improving employee morale, and reducing cost for both manufacturers and suppliers (Kunovjanek et al. 2020; Caprihan et al. 2013).

According to EL-Khalil (2009), FMS implementation positively influences employee morale, supplier and manufacturer's communication, reduction of waste and hazardous material, cost, and quality. Gunasekaran (1999 a,b) describes the influence of flexibility on strategic planning and sustainability. Ojsteresek and Buchmeister (2020) discussed the link between sustainability (economic, social, and environmental) and flexibility in manufacturing. They indicate that certain sustainability initiatives might hurt some operational performance metrics due to the initial cost of implementation and the learning curve. According to Cicullo et al. (2018), efficient communication between suppliers and manufacturers will directly improve all operational performance metrics. According to Geyi et al. (2020); Qamar et al. (2020); Delic et al. (2019); Cicullo et al. (2018); Wilson and Paltts (2010) flexibility attributes such as labor, volume, machine, and others can be linked to sustainability. They recommended that future research should focus on investigating such interaction in the manufacturing industry.

H1: Flexibility practices have a positive effect on sustainability performance.
H2: Flexibility practices have a positive effect on operational performance.

3.2 The impact of supply chain practices on operational performance metrics and sustainability performance.

According to Eckstein et al. (2015), existing literature agrees on the impact/influence of sustainability practices on strategic innovation and cost. Chavez et al. (2020); Matos et al. (2020); Aslam et al. (2018); Blome et al. (2014); Carter and Rogers (2008); Croom et al., (2000), discuss the importance of sustainability (economic, social, and environmental) and how its implementation provides a competitive advantage for any organization, manufacturing or services industry. According to the 2020 US department of energy report on sustainability (EPA 2020), sustainability implementation in US organizations leads to a cost-saving that ranged between 10-15% of the total annual cost. According to Delic and Eyers (2020), an increase in the level of sustainability implementation will result in a direct improvement in innovation and high-cost savings. According to Katiyar (2018), sustainability practices can lead to an improvement in organizational and sustainability performance. According to Grimm et al. (2014) and Gunasekaran (2001) argue that some companies are hesitant in sustainability implementation due to its high initial cost. They also discuss that the long-term benefits achieved through sustainability implementation justify any high initial/short term cost. According to Grimm et al. (2014) sustainability (social and economic), directly leads to improving employee morale and that intern will result in improving quality.

Sustainability performance relies heavily on the performance of every stage and element of the supply chain (Chen et al., 2017). According to Katiyar et al. (2018), every element of the supply chain practices directly impacts sustainability. For example, the planning, sourcing, and delivery dimensions of the supply chain include effective resource management, which directly leads to impacting sustainability (EPA 2020). Esfahbodi et al. (2017) indicate that cost associated with every supply chain dimension is critical to the overall countries economy. He explained that this cost of delivery dimension is the highest of all supply chain costs, it accounts for 12% of the world gross domestic product (GDP). Through collaborative work between suppliers and manufacturers, such costs can be significantly reduced (Ganeshan et al., 2001). According to Gunasekaran (1998), improving supply chain performance dimensions will rely on multiple attributes such as the agility of the process, lead time, efficiency, and effectiveness of the operating mode (i.e. sourcing, delivery, packaging etc). Gunasekaran et al. (2001) discuss the importance of an efficient supply chain. They indicate that the closer the connection between the supplier and the manufacturers the higher the efficiency. The above mentioned leads us to the following hypotheses:

H3: Sustainable supply chain practices have positive effects on operational performance.
H4: Sustainable supply chain practices have positive effects on sustainability performance.
3.3 Mediation effect of flexibility and impact of sustainability on flexibility
Flexible manufacturing systems practices involve fifteen different dimensions that focus on every aspect of the manufacturing process. Those dimensions/practices focus on issues such as technology, suppliers, materials, labor, equipment, and their ability to adjust to changes with minimum impact on the overall operational performance. Delic and Eyers (2020); Ojstersek and Buchmeister (2020); Kaur et al. (2017) discussed enablers for successful supply chain implantation. They indicate that most of those enablers are affiliated with flexibility practices. According to KRONOS (2016) in its report to the US government regarding the future of the manufacturing industry 2020 and beyond, the survivor of the manufacturing industry will depend on its ability to adopt flexible manufacturing practices, strengthen its supply chain (focus on improving the relationship between suppliers, manufacturers, and customers), and implement sustainability practices that can help with short and long term problems (economic, social and environmental). Mendes and Machado (2015) indicate that collaborative network capabilities have a direct and positive influence on supply chain and sustainability, it provides common resources, improves communication (internal and with suppliers), improves quality, and reduces cost. Angkiriwang et al. (2014) presented a model that improves supply chain flexibility while linking it to environmental uncertainties. According to Gunasekaran et al. (2001), the impact of sustainability practices in manufacturing will significantly increase when facilitated through lean and or flexible practices. The following hypotheses can be proposed:

H5: Flexibility practices mediate the relationships between sustainable supply chain practices and sustainability performance
H6: Flexibility practices mediate the relationships between sustainable supply chain practices and operational performance.

Blome et al. (2014) indicate that part of adjusting to customer needs through the creation of a new sustainable product will force organizations to develop a lean and flexible process. EL-Khalil (2020) discusses how creating sustainable supply chain practices will support the implementation of a lean and flexible process. The implementation of sustainable supply chain practices supports innovative manufacturing philosophies such as flexibility and leads to improving the performance of the overall system (Johnzen et al. 2011). Therefore, the following are thus proposed:

H7: Sustainable supply chain practices have positive effects on flexibility practices.

4. Research Methodology
The conceptual model presented in this research consists of four constructs identified by the literature review and practitioners/experts at the Big Three. The model constructs include supply chain performance, sustainability performance, flexibility performance, and operational performance metrics. The model construct and indicators are presented in Figure 1 and Appendix B.

A survey questionnaire was developed based on the proposed model. This questionnaire was designed to investigate the role of flexibility in the relationship between a sustainable supply chain and operational performance metrics. The variables utilized in the questionnaire were originally developed from several empirical studies (Nath and Argawal 2020; Geyi et al. 2020; Katiyar et al. 2018; Cosimato and Troisi 2015; Ninlawan et al. 2010), on the impact of the sustainable supply chain (planning, Delivery, sourcing) on performance in India (automotive industry) and United Kingdom (energy industry). This survey was then altered based on the literature review and expert opinion at the automotive facilities studied. The survey is divided into two categories. The first part encompasses questions related to demographics; those questions investigate the facility type respondent’s experience, position, gender, education, company annual sales, number of employees, ownership (domestic or foreign), and year of philosophy implementation (sustainability and flexibility), as illustrated in Table 4. The second category of questions involves the model constructs/dimensions. As presented in Figure 1 and Appendix B, each construct involves multiple indicators (Katiyar et al. 2018; Aslam et al. 2018; Newman et al. 1993). It is worth mentioning that the implementation of flexible manufacturing systems is fairly new. Most of the manufacturing companies started the flexibility implementation at the end of the 20th century (EL-Khalil 2020). The facilities included in this survey are all located in the United States.

The model constructs were divided into multiple indicators (Katiyar et al. 2018). A seven-point Likert scale was established for each variable within the model constructs presented, 1 and 7 were “no implementation = 0%” and “excellent/complete implementation = 100%” respectively (Katiyar et al. 2018). The survey included five questions
regarding operational metrics: cost, quality, delivery, productivity, and safety (EL-Khalil and Darwish, 2019; Shah and Ward 2007; Gunasekaran 1998). A seven-point Likert Scale was utilized for each of the five performance metrics.

<table>
<thead>
<tr>
<th>Relevance Dimensions</th>
<th>Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Manufacturing Industry</td>
<td>55% Automotive Assembly and Powertrain (all are Original Equipment Manufacturer “OEM”)</td>
</tr>
<tr>
<td>30% Computer and Electronic</td>
<td></td>
</tr>
<tr>
<td>15% Appliances and Components</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>79% Male</td>
</tr>
<tr>
<td>21% Female</td>
<td></td>
</tr>
<tr>
<td>Position</td>
<td>49% Operations/Production Managers</td>
</tr>
<tr>
<td>21% Facility/Plant Managers</td>
<td></td>
</tr>
<tr>
<td>12% Engineering Managers</td>
<td></td>
</tr>
<tr>
<td>14% Quality and Material Handling Managers</td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>7% PhD/DBA</td>
</tr>
<tr>
<td>84% Masters Degree</td>
<td></td>
</tr>
<tr>
<td>9% BS/BA</td>
<td></td>
</tr>
<tr>
<td>Years of Experience</td>
<td>83% &gt; 15 years</td>
</tr>
<tr>
<td>17% 10-15 Years</td>
<td></td>
</tr>
<tr>
<td>Company size Annual Sales</td>
<td>64% $1 billion +</td>
</tr>
<tr>
<td>25% $100 - $999 million</td>
<td></td>
</tr>
<tr>
<td>11% &lt; $100 million</td>
<td></td>
</tr>
<tr>
<td>Number of Employees</td>
<td>72% &gt; 1000 employees</td>
</tr>
<tr>
<td>28% 1000 - 100 employees</td>
<td></td>
</tr>
<tr>
<td>0% &lt; 100</td>
<td></td>
</tr>
<tr>
<td>Ownership</td>
<td>80% Domestic</td>
</tr>
<tr>
<td>20% Foreign</td>
<td></td>
</tr>
<tr>
<td>Sustainability implementation (Number of years)</td>
<td>61% &gt; 10 years</td>
</tr>
<tr>
<td>25% 5 - 10 years</td>
<td></td>
</tr>
<tr>
<td>14% 5 years</td>
<td></td>
</tr>
<tr>
<td>FMS implementation (Number of years)</td>
<td>81% &gt; 15 years</td>
</tr>
<tr>
<td>19% 5 - 15 years</td>
<td></td>
</tr>
</tbody>
</table>

4.1 Data analysis and validation

This paper uses Partial Least Squares (PLS) is assigning the proposed model (Delic et al. 2020; EL-Khalil and Darwish 2019; Katiyar et al. 2018; Aprile et al. 2005; Fornell and Larcker 1981). According to Delic et al. (2020) and Fornell and Larcker (1981), In comparison with covariance-based equation modeling, PLS is more suitable for small sample size and it does not require data to be normally distributed. In line with the work conducted by Delic et al. (2020), EL-Khalil and Darwish (2019), and Katiyar et al. (2018) SmartPLS was utilized for analysis, at 5000 samples (bootstrap) to compute t-values.

The validation of the survey and questionnaire was conducted by four directors/senior managers at the Big Three (North America) involved in the design and implementation of the constructs presented in this research. Four academicians (in the State of Michigan) with extensive experience in industry and academia tested the survey questionnaire.

4.2 Data and review

Over two and a half years (started in June 2018) 396 manufacturing facilities were contacted through phone and emails (144 automotive, 132 computer and electronic, 120 appliances and automotive component) and asked to participate through a face-to-face interview (either by inviting the author for a physical visit to facilities or by virtual meeting online). The facilities contacted are all located in North America (the United States, Canada, and Mexico). The author’s background is in the manufacturing industry (Automotive) and works as a consultant for several manufacturing companies in North America. Several directors and senior managers in the automotive industry were contacted originally and asked to review the model establish based on the literature review conducted. They were asked to make changes to the proposed questionnaire-based practical experience. After establishing the final questionnaire, a total of 114 managers and directors agreed to participate (80 physical visits, and 34 virtual meetings),
demographics illustrated in Table 4. 101 interviews were used for analysis for 101 different facilities (19 different companies). Out of the 34 virtual meetings, only 13 were useful due to connection issues and missing data.

5. Model Results
5.1 Model measurements
The constructs presented in the proposed model are reflective latent variables rather than formative. Indicators presented under each construct are used to define it. According to Katiyar et al., (2018); Tenenhaus et al., (2005); Fornell and Larcker, (1981), for variables to be considered as reflective, the model should be subjected to convergent validity, indicator reliability, construct reliability tests, and discriminant validity. The model result, as illustrated in Table 5.

Table 5. Model Results
### 5.1.1 Convergent and discriminant validity

Convergent validity can be conducted utilizing composite reliability, average variance extracted (AVE), and item loading (Katiyar et al., 2018). According to Fornell and Larcker, (1981), for convergent validity, the value of all measures should be greater than 0.5. Table 5 indicates that AVE, composite reliability, and item loading for all constructs is higher than the 0.5 thresholds. This result indicates the convergent reliability of the model.

The discriminant validity for the model can be determined by comparing “the value with the square root of the average variance extricated in the diagonal with the correlation among constructs” (Fornell and Larcker, 1981). The square root of AVE for each construct “must be greater than the inter-correlations with the other constructs” (Tenenhaus et al., 2013).
al., 2005). Table 6, indicates a strong correlation of construct with their items. Therefore, the model meets the requirements of discriminant validity; the model is valid and reliable.

Table 6. Correlation matrix (first order model)

<table>
<thead>
<tr>
<th></th>
<th>Flexibility</th>
<th>SCP</th>
<th>Sustainability</th>
<th>OPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexibility</td>
<td>0.953</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCP</td>
<td>0.761**</td>
<td>0.909</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sustainability</td>
<td>0.946**</td>
<td>0.849**</td>
<td>0.967</td>
<td></td>
</tr>
<tr>
<td>OPM</td>
<td>0.777**</td>
<td>0.887**</td>
<td>0.827</td>
<td>0.902</td>
</tr>
</tbody>
</table>

Diagonal elements represent latent variable AVE square root

5.2 Hypothesis testing

The structural model was utilized to investigate the relationships for the latent variables. According to Fornell and Larcker (1981), assessing the structural model requires investigating the goodness of fit (GoF) and endogenous variable coefficient ($R^2$); they should be higher than 0.1. Figure 2 illustrates the SmartPLS structural model results.

The $R^2$ (Endogenous variable coefficient of determination) for operational performance metrics is 0.819, this indicates that the proposed model explains 81.9 percent of the operational performance variance. The $R^2$ for flexibility and sustainability are 0.551 and 0.934, respectively. The explained variance is significant for all (model) endogenous variables. The GoF value is 0.881 which is an indication of a substantial model fit and is suitable for evaluating the path significance.

![Figure 2. Structural Model results (SmartPLS)](image)

Testing hypothesis H1-H7, along with results determining T-statistics, path coefficient, and P-value is illustrated in Table 7. The hypothesis H1 (i.e. the relationship between Flexibility and OPM), hypothesis H2 (i.e. the relationship between Flexibility and Sustainability), the hypothesis H3 (i.e. the relationship between Sustainable supply chain practices “SSCP” and OPM), the hypothesis H4 (i.e. the relationship between SSCP and Sustainability), the hypothesis H5 (i.e. the relationship between SCP, Flexibility, and Sustainability), the hypothesis H6 (i.e. the relationship between SSCP, Flexibility, and OPM), the hypothesis H7 (i.e. the relationship between SCP and Flexibility) are supported with a significance level $p < 0.01$, $p < 0.001$, $p < 0.001$, $p < 0.001$, $p < 0.001$, $p < 0.001$, $p < 0.001$ respectively. The results indicate that the performance in all areas of the model is positively impacting the Operational performance metrics (OPM) in the automotive manufacturing industry in North America. Table 7 implies (H5) the mediating influence of
flexibility practices on the relationship between sustainable supply chain practices and operational performance and (H6) the mediating influence of flexibility on the relationship between sustainable supply chain and operational performance. The results indicate that the mediation effect of flexibility leads to higher sustainability and operational performance outcomes. The model shows a Standardized root mean square residual (SRMR) = 0.031 in comparison to the recommended value below 0.06 by Fornell and Larcker (1981). The Normed Fit Index (NFI) = 0.913 and the Comparative fit index (NFI) = 0.934 are greater than 0.9 recommended by Tenenhaus et al. (2005), and a Chi-squared less than 2 according to Geyi et al. (2020). The indicator presented shows a strong mediation, the effect of flexibility in supporting and amplifying the impact of the sustainable supply chain, and sustainability on operational performance in the automotive industry is irrefutable.

Table 7. Hypothesis testing results using partial least squares

<table>
<thead>
<tr>
<th>Hypotheses</th>
<th>Path Coefficient</th>
<th>T-statistics</th>
<th>P-value</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>Flexibility → Sustainability</td>
<td>0.727**</td>
<td>13.03</td>
<td>0.000</td>
</tr>
<tr>
<td>H2</td>
<td>Flexibility → OPM</td>
<td>0.264**</td>
<td>3.255</td>
<td>0.001</td>
</tr>
<tr>
<td>H3</td>
<td>SSCP → Sustainability</td>
<td>0.295**</td>
<td>4.926</td>
<td>0.000</td>
</tr>
<tr>
<td>H5</td>
<td>SSCP → Flexibility → Sustainability</td>
<td>0.726**</td>
<td>4.679</td>
<td>0.000</td>
</tr>
<tr>
<td>H6</td>
<td>SSCP → Flexibility → OPM</td>
<td>0.265**</td>
<td>3.276</td>
<td>0.000</td>
</tr>
<tr>
<td>H7</td>
<td>SSCP → Flexibility</td>
<td>0.743**</td>
<td>15.381</td>
<td>0.000</td>
</tr>
</tbody>
</table>

5.3 Discussion and implication

5.3.1 The effect of the sustainable supply chain on flexible manufacturing practices
The result indicates a significant correlation between flexibility and sustainable supply chain practices. This relationship suggests that an increase in implementing a sustainable supply chain will lead to an increase in the development of flexibility. The correlation matrix indicated a coefficient value above the 0.7 thresholds and the Kaiser-Meyer-Olkin value was 0.887 (recommended above 0.6), Bartlett’s of Sphericity value of 0.000, therefore supporting factorability of the matrix (Fornell and Larcker 1981). The correlation matrix of model principle components as illustrated in Appendix C.

The component of sustainability indicates a strong positive correlation with all components of flexibility. Higher sustainable supply chain implementation in coordination with the implementation of higher flexibility will lead to a direct improvement in organization objectives. Based on the model results and correlation matrix, the strongest relationships (between components) are between Necessary flexibility and planning, make, return, assembly, delivery, sourcing, and packing respectively (sustainable supply chain components). This result agrees with Geyi et al. (2020), who indicate that a sustainable supply chain should lead to an improvement in flexibility. The strongest relationships for all three flexibility components are with planning, make, and assembly (sustainable supply chain). This suggests that organizations can focus on improving specific components over others based on the organizational objective. As consumer demand and organizational strategic planning shift to achieve a different level of sustainability (product and or process), the organization needs to adjust its focus on implementation accordingly. In comparison with the previous research conducted by Delic and Eyers (2020); Aslam et al. (2018); Ciccullo et al. (2018); Chen et al. (2017); Carter and Roger (2008); Berry and Ahmed (1997), the sustainable supply chain components as well as sustainability performance (based on our study) includes more components and variables that have a significant impact on each other as well as on flexibility and operational performance.

5.3.2 The effect of flexibility on sustainability and operational performance
Flexible manufacturing systems (flexibility) practices components have a significant positive impact on operational performance and sustainability performance. The finding presented in this research is consistent with prior studies that indicated an increase in flexibility practices implementation would lead to an increase in operational performance (Nader et al. 2022; Delic and Eyers 2020; EL-Khalil and Darwish 2019; Katiyar et al. 2018; Yusuf et al. 2013; Blome et al. 2014; Caprihan et al. 2013). Previous studies were limited in-depth and breadth that investigated the dimensions of flexibility and operational performance; what is also new about this research is its study of the connection between flexibility and sustainability. The flexibility practices accounted for 82 and 91% of the variance in operational performance and sustainability. The correlations matrix indicates that the highest flexibility components affecting operational performance are sufficient, necessary, and competitive. Moreover, for sustainability components, it is necessary, competitive, and sufficient, respectively. Investing in flexibility will allow organizations to react faster.
will minimum or no impact on the overall process; such advancement will support long-term growth, improve the organization’s relationship with its employees, and reduce the negative environmental impact. The flexible manufacturing systems implementation support sustainability by reducing cost, eliminating waste, reducing energy consumption, and significantly improving lead-time (Narain et al. 2000). According to Delic and Eyers (2020), flexibility involves manufacturers and suppliers working together in establishing a sustainable process with design, creating, and maintaining a process by which nature and humans can co-exist in harmony to improve the present and future generations (socially, economically, and environmentally).

5.3.3 The mediating role of flexibility practices
The findings presented in this study confirm the mediating role of flexibility practices in the relationship between supply chain practices and operational performance, as well as supply chain practices and sustainable practices. The findings contradict some of the previous work conducted by Gupta and Barua. (2018); Katiyar et al. (2018); Jadhav et al. (2019), in regards to the impact of supply chain and sustainability components. According to Kaur et al. (2017) and Nader et al. (2022), the successful implementation of sustainability requires understanding and knowledge of stakeholders and customers. Organizations that acquire flexibility can react more efficiently to customer demand fluctuations and are more effective in changing and adjusting strategies and objectives to fit that fluctuation. Flexibility provides leverage for organizations to react to customer demand fluctuations and to adjust organizational variables such as machinery, manpower, processes, suppliers, material, and technology efficiently with minimal or no impact on the organizational output. The findings of this research suggest that previous work conducted by EL-Khalil and Darwish (2019); Slack (2005); Sethi and Sethi (1990); Gunasekaran (1998); Brown et al. (1984) on flexibility influence on operational performance and categorization of flexibility dimensions varies drastically. In comparison with previous research conducted by Durugbo and Al-Balushi (2022); Ivanov and Doigui (2022); Geyi et al. (2020); Delic et al. (2019); Aslam et al. (2018); Katiyar et al. (2018), it is clear that when introducing new constructs/variables such as flexibility to study its effects on sustainable supply chain practices and operational performance significant changes occur. For example, Geyi et al. (2020) indicate that social and environmental is the highest on sustainable supply chain and flexibility. This research indicates the economic component of sustainability had a higher influence than the social and environmental components. The flexibility components studied indicated different effects and significance than previously mentioned by authors such as El-khalil and Darwish (2019); Mendes and Machado (2015); Narain et al. (2000); Vokurka and O’Leary (2000). The competitive component of flexibility indicated higher positive significance (mediating) than the sufficient component.

5.3.4 Theoretical and managerial Implication
This research paper contributes to policy, practice, and theory for understanding the role of flexibility practices and their contribution in supporting sustainable supply chain performance for achieving improvements in operational performance in the automotive manufacturing industry. Today’s automotive industry is more competitive than ever before. According to Deloitte (2019) adopting innovative philosophies and implementing them successfully is the key. Geyi et al. (2020); Aslam et al. (2018); KRONOS (2016), indicates that dynamic capability provides critical support for achieving competitiveness in manufacturing. Efficient use of resources and the ability to adjust to changes is the cornerstone of competitiveness. This paper provides insight into the relationships between sustainability, supply chain, flexibility, and operational performance. The findings confirm that sustainable supply chain practices are drivers for flexibility. The results show that flexibility has a direct and positive impact on operational performance and sustainability. The results also show that the implementation of sustainable supply chain practices (planning, sourcing, delivery, make, assembly, packing, and return) will directly impact (positively) sustainability (economics, social, and environmental), therefore supporting competitive objectives. This study contributes to the broader literature in the discipline of operation and production management by providing imperial evidence on the influence and effect of flexibility, supply chain, and sustainability practices on operational performance in the automotive manufacturing industry. What is unique in this study is the breadth, and depth by which constructs and variables are tested. In addition, the study addresses the importance of flexibility in amplifying the impact of a sustainable supply chain on performance. The results show that stockholders’ concerns must be accommodated (from a sustainability point of view), otherwise placing the supply chain under serious risk.

The study provides practitioners with insight on the impact of sustainable supply chain constructs on operational performance and the role of flexibility in amplifying that impact. Sustainable processes and products are important in supporting competitiveness and achieving social, environmental, and economic sustainability. Through implementing a flexible and sustainable strategy, an organization can develop a flexible manufacturing process that is capable of adjusting to customer demand changes. This research provides a contemporary in-depth understanding of measuring
operational performance by including supply chain, sustainability, and flexibility. Data findings recommend that managers implement all seven constructs of the supply chain practices. The empirical evidence presented indicates a positive relationship between supply sustainable chain performance, flexibility, and operational performance will inspire managers to implement sustainability to improve organizational performance. Data emphasizes the importance of involving suppliers and employees at every level of the organization in sustainability initiatives. Close and constant involvement by all stakeholders is critical for efficient and effective problem resolution related to every aspect of the sustainable process. Reducing cost, improving lead-time, improving quality, and addressing short and long-term problems requires a comprehensive and concurrent implementation of flexible manufacturing systems, supply chain practices, and sustainability. This paper shows that increasing the implementation of specific constructs (flexibility, supply chain, and sustainability) or variables will lead to different positive output in operational performance. It is good to note that concurrent implementation will maximize results. Managers interviewed indicated reluctance in sustainability implementation due to initial cost, disbelief in benefits, training, union-related problems, …etc. The study result should serve as a tool that shows the direct and positive link between sustainability, flexibility, supply chain implantation, and operational performance. The sustainability implementation will also help improve the organizational image through its commitment to social, economic, and environmental objectives.

6. Conclusion and Research Limitation

The implementation of sustainability is a vital element of an effective organizational culture. Addressing current stockholders’ needs (internal and external) without jeopardizing the ability to meet future generation needs is critical for the survival of any organization. Planning, designing, and implementing a system and or process that preserve and improve natural, economic, and social resources is a key to competitiveness. According to IMD (2020), 74% of executives indicate that sustainability is critical for competitiveness.

The study provides empirical evidence from the automotive industry on the role of flexibility in improving the impact of the supply chain on operational performance as well as on sustainability. The results also indicate a positive influence of sustainability practices on improving competitiveness. This influence increase when facilitated with flexibility. The results are a clear indication of the positive and significant role of flexibility in improving organization performance, especially when an organization is implementing a sustainable supply chain process. The paper provides an insight into the impact of flexibility on supply chain and sustainability practices and the significance of each construct in improving organizational performance.

The paper provides an in-depth assessment of supply chain practices, sustainability, and flexibility practices. The depth and breadth of variables presented in this model are unique and it is driven by practical contemporary application from the automotive industry in North America. Future research should investigate the impact of strategic planning on flexible supply chain performance. It can also investigate more into the interactions of specific elements of flexibility with specific sustainable supply chain practices.

This research focused only on the automotive manufacturing industry in North America. The result may not be a reflection of all the manufacturing industry. Adding other manufacturing companies such as electronics, appliances, etc. and others can improve and strengthen such research. This provides an opportunity for future researchers. The results are limited to the North American automotive industry context where the implementation of such philosophies (flexible manufacturing, sustainability) is widespread in comparison to other continents or countries. Therefore, when replicating such a study, research needs to investigate the year of implementation.

Appendix A: The constructs and their indicators (Supply Chain)
Appendix B: The Model constructs and their indicators
### Appendix C: Correlation metrics

<table>
<thead>
<tr>
<th>Operational Performance Metric (OPM)</th>
<th>Operational Performance Metric (OPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>Cost</td>
</tr>
<tr>
<td>Quality</td>
<td>Quality</td>
</tr>
<tr>
<td>Delivery</td>
<td>Delivery</td>
</tr>
<tr>
<td>Efficiency and Effectiveness</td>
<td>Efficiency and Effectiveness</td>
</tr>
<tr>
<td>Improved compliance with environmental standards</td>
<td>Improved compliance with environmental standards</td>
</tr>
</tbody>
</table>

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References


Berry, T., and Ahmed, A. The consequences of internal supply chains for management accounting. Management Accounting, vol. 75, no. 10, pp. 74-75, 1997


**Biography**

Raed EL-Khalil is an Industrial Engineering Manager at Ford Motor Company. He holds a Doctorate in Industrial and Manufacturing engineering from Lawrence Technological University and several Masters and BS engineering degrees from the University of Michigan. He was also an associate professor at Lebanese American University and Adrian College, where he still teaches as part-time faculty. In addition, he has over 26 years of manufacturing experience working in production and engineering at foreign and domestic companies such as Chrysler, GM, Toyota, and Nissan. His research focuses on lean, flexible, and agile manufacturing systems, sustainability, robotics, and operations management. He has over 71 publications in top-ranked journals such as the International Journal of Production Economics (2022), the International Journal of Lean and Six Sigma (2020), and Production planning and control (2019). His ORCID: [https://orcid.org/0000-0002-2514-1120](https://orcid.org/0000-0002-2514-1120).