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

Deloitte Inc., in its 2019 report on manufacturing, identified twelve drivers of global manufacturing competitiveness (Deloitte 2019). Innovation and Talent was the most crucial global manufacturing driver. According to Deloitte (2019), the primary driver component of innovation is flexible manufacturing systems (FMS). The increasing competition among organizations in addition to the fluctuating market forced many organizations to start implementing FMS. Sethi and Sethi (1990) explained that very few studies practical/theoretical investigated the concept and dimensions of flexibility and its impact on improving operational performance. Slack (2005) and El-Khalil (2009) explain that flexibility implementation is a critical component to achieving competitiveness in today's manufacturing industry. Shah and Ward (2007) consider flexibility as a primary driver for any organization that seeks to improve its performance. Geyi et al. (2020) indicated the importance of flexibility and the need for more research investigating the impact of flexibility on manufacturing systems and processes.

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 is to create long-term value while taking into consideration the social, economic, and ecological environment (Vinodh

2010). 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 1. FMS dimensions, classifications, and definitions

Level	#	Flexibility Type	Definition
Necessary flexibility			
Operational (focus)	1	Machine	Refers to the ability of the system to switch operation without requiring major effort
	2	Material Handling	The ability to move different part types efficiently for proper positioning and processing
	3	Operation	The ability of the part to be produced in different ways with alternative process plans
	4	Automation	The capability of the automation to perform different operation and or add operation
	5	Labor	The ability to change number of workers, tasks performed by workers, and responsibility
	6	Process	Relates to the set of part types that the system can produce without major set-up
	7	Routing	The ability to produce a part by alternative routes
Sufficient flexibility			
Tactical (focus)	8	Product	The ease with which new parts can be added or substituted for the existing parts
	9	New Design	The ease by which the system produces a product with different shapes and/or dimensions
	10	Delivery	The ease to transporting material to the manufacturing facility, as well as to operation within the facility
	11	Volume	The ability to be operated profitably at different product overall output levels
Competitive flexibility			
Strategic (focus)	12	Expansion	The ease with which the capacity and capability can be increased when needed
	13	Program	The ability of the system to run virtually untended for a long enough period
	14	Production	The universe of part types that the FMS can produce
	15	Market	The ease with which the manufacturing system can adapt to a changing market environment

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 Newel (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).

Supply chain performance can be measured using several metrics. Chen and Paulraj (2004) utilized both buyer performance and supplier performance to examine the relationship between supply management, strategic planning, financial performance, and customer responsiveness. Vickery et al. (2003) studied the integration of supply chain strategy, customer service performance, and financial performance and their implications on the organization's performance. To evaluate the predictive validity of the six supply chain management constructs, Li et al. (2005) utilized both times to market and deliver dependability. Narasimhan and Kim (2002) investigated the impact of the supply chain management relationship between firm performance, diversification, and integration. Tan (2002) utilized the competitive position, customer service levels, and overall product quality as performance metrics.

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

Authors	Definition
Jones and Riley (1985)	An integrative approach to dealing with the planning and control of the materials flow from suppliers to end-users.
Ellram (1991)	A network of firms interacting to deliver product or service to the end customer, linking flows from raw material supply to final delivery.
Christopher (1992)	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.
Lee and Billington (1992)	Networks of manufacturing and distribution sites that procure raw materials, transform them into intermediate and finished products, and distribute the finished products to customers.
Berry et al. (1994)	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.
Saunders (1995)	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.
Kopczak (1997)	The set of entities, including suppliers, logistics services providers, manufacturers, distributors and resellers, through which materials, products and information flow.
Lee and Ng (1997)	A network of entities that starts with the suppliers' supplier and ends with the customers' custom the production and delivery of goods and services.
Tan et al. (1998)	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.

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

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

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); Cicculo et al. (2018), indicated a lack of empirical study testing the impact of flexible manufacturing systems on sustainable supply chain performance.

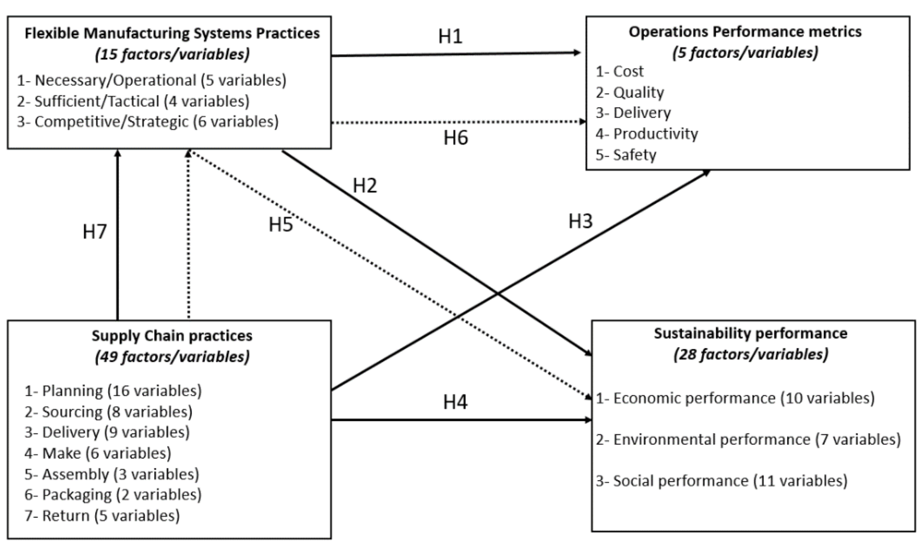

Figure 1. Conceptual model and hypotheses

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 Cicculo 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); Cicculo 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 overall performance. 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 4. Demographics - Participated companies and respondents

Relevant Dimensions	Profile
Type of Manufacturing Industry *(all are Original Equipment Manufacturer "OEM")*	55% Automotive Assembly and Powertrain 30% Computer and Electronic 15% Appliances and Components
Gender	79% Male 21% Female
Position	49% Operations/Production Managers 21% Facility/Plant Managers 12% Engineering Managers 14% Quality and Materials Handling Managers
Education	7% PhD/DBA 84% Masters Degree 9% BS/BA
Years of Experience	83% > 15 years 17% 10-15 Years
Company size Annual Sales	64% $1 billion + 25% $100 - $999 million 11% < $100 million
Number of Employees	72% > 1000 employees 28% 1000 - 100 employees 0% < 100
Ownership	80% Domestic 20% Foreign
Sustainability implementation (Number of years)	61% > 10 years 25% 5 - 10 years 14% < 5 years
FMS implementation (Number of years)	81% > 15 years 19% 5 - 15 years
n = 101	

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

Latent variable/Construct		Indicators	Outer weight	Loading	Communality	AVE	CR	Cronbach's - α
Supply Chain Practices						0.827	0.971	0.965
Planning Performance	*Order Planning*	SCP1	0.27	0.806	0.732			
		SCP2	0.24	0.766	0.718			
		SCP3	0.27	0.766	0.7			
		SCP4	0.29	0.797	0.772			
		SCP5	0.25	0.704	0.688			
		SCP6	0.28	0.797	0.773			
	Tactical Planning	SCP7	0.3	0.744	0.76			
		SCP8	0.29	0.773	0.742			
		SCP9	0.27	0.771	0.689			
		SCP10	0.260	0.748	0.766			
		SCP11	0.300	0.799	0.762			
		SCP12	0.280	0.826	0.764			
	Inventory Strategy	SCP13	0.290	0.882	0.813			
		SCP14	0.280	0.858	0.811			
		SCP15	0.310	0.824	0.835			
		SCP16	0.310	0.839	0.806			
Sourcing Performance	*Strategic*	SCP17	0.250	0.840	0.815			
		SCP18	0.190	0.754	0.67			
	Tactical	SCP19	0.260	0.745	0.682			
		SCP20	0.270	0.760	0.725			
		SCP21	0.260	0.757	0.791			
		SCP22	0.260	0.711	0.738			
		SCP23	0.270	0.785	0.775			
	Operational	SCP24	0.220	0.723	0.803			
Delivery Performance		SCP25	0.190	0.744	0.804			
		SCP26	0.200	0.722	0.844			
		SCP27	0.300	0.840	0.756			
		SCP28	0.280	0.823	0.79			
		SCP29	0.280	0.827	0.772			
		SCP30	0.260	0.776	0.701			
		SCP31	0.250	0.797	0.792			
		SCP32	0.280	0.814	0.733			
		SCP33	0.290	0.839	0.798			
Make		SCP34	0.210	0.721	0.837			
		SCP35	0.250	0.733	0.776			
		SCP36	0.280	0.835	0.791			
		SCP37	0.260	0.772	0.822			
		SCP38	0.280	0.823	0.832			
		SCP39	0.310	0.780	0.825			
Assembly		SCP40	0.260	0.757	0.786			
		SCP41	0.320	0.815	0.804			
		SCP42	0.240	0.758	0.744			
Packaging		SCP43	0.280	0.787	0.848			
		SCP44	0.290	0.815	0.791			
Return		SCP45	0.170	0.775	0.865			
		SCP46	0.240	0.741	0.802			
		SCP47	0.270	0.796	0.748			
		SCP48	0.230	0.705	0.713			
		SCP49	0.220	0.711	0.789			
Flexibility Practices (Flexible Manufacturing systems)						0.909	0.968	0.95
Necessary/operational		FMS1	0.22	0.811	0.74			
		FMS2	0.24	0.791	0.764			
		FMS3	0.19	0.878	0.753			
		FMS4	0.21	0.831	0.716			
		FMS5	0.19	0.832	0.723			
Sufficient/Tactical		FMS6	0.19	0.831	0.753			
		FMS7	0.18	0.854	0.769			
		FMS8	0.19	0.819	0.805			
		FMS9	0.18	0.824	0.814			
Competitive/Strategic		FMS10	0.19	0.854	0.795			
		FMS11	0.19	0.844	0.768			
		FMS12	0.17	0.867	0.753			
		FMS13	0.21	0.831	0.704			
		FMS14	0.18	0.835	0.758			
		FMS15	0.22	0.799	0.827			
Sustainability Performance Criteria						0.937	0.978	0.967
Economic performance		SUSEC1	0.43	0.849	0.801			
		SUSEC2	0.42	0.832	0.767			
		SUSEC3	0.45	0.857	0.762			
		SUSEC4	0.43	0.849	0.839			
		SUSEC5	0.42	0.791	0.838			
		SUSEC6	0.44	0.842	0.784			
		SUSEC7	0.46	0.87	0.838			
		SUSEC8	0.43	0.832	0.818			
		SUSEC9	0.45	0.831	0.749			
		SUSEC10	0.44	0.844	0.743			
Environmental performance		SUSEN1	0.360	0.722	0.74			
		SUSEN2	0.400	0.777	0.771			
		SUSEN3	0.410	0.802	0.766			
		SUSEN4	0.420	0.846	0.811			
		SUSEN5	0.450	0.866	0.792			
		SUSEN6	0.440	0.877	0.747			
		SUSEN7	0.450	0.874	0.715			
Social performance		SUSSC1	0.37	0.72	0.751			
		SUSSC2	0.390	0.78	0.793			
		SUSSC3	0.420	0.823	0.778			
		SUSSC4	0.420	0.847	0.761			
		SUSSC5	0.440	0.862	0.785			
		SUSSC6	0.420	0.834	0.807			
		SUSSC7	0.430	0.844	0.862			
		SUSSC8	0.440	0.861	0.84			
		SUSSC9	0.450	0.895	0.793			
		SUSSC10	0.44	0.866	0.748			
		SUSSC11	0.43	0.864	0.797			
Operational Performance Metrics						0.814	0.956	0.943
	Cost	OPM1	0.217	0.898	0.838			
	Quality	OPM2	0.225	0.906	0.788			
	Delivery	OPM3	0.223	0.913	0.824			
	Productivity	OPM4	0.223	0.899	0.786			
	Safety	OPM5	0.221	0.895	0.821			

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., 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)

	Flexibility	SCP	Sustainability	OPM
Flexibility	***0.953***			
SCP	0.761**	***0.909***		
Sustainability	0.946**	0.849**	***0.967***	
OPM	0.777**	0.887**	0.827	***0.902***

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.

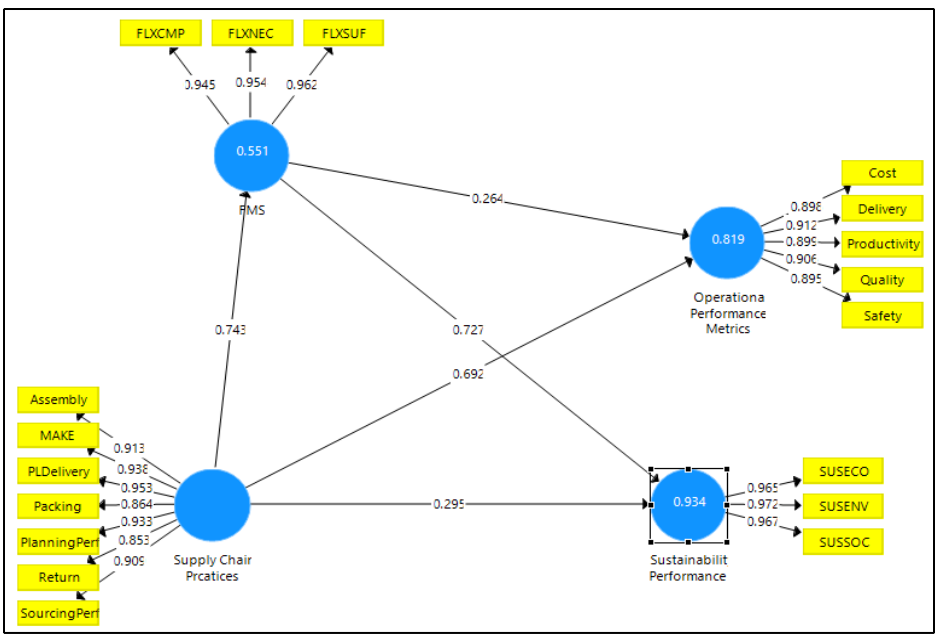

Figure 2. Structural Model results (SmartPLS)

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

Hypotheses	Path	Path Coefficient	T-statistics	P-value	Results
H1	Flexibility →Sustainability	0.727**	13.03	0.000	Supported
H2	Flexibility →OPM	0.264**	3.255	0.001	Supported
H3	SSCP →Sustainability	0.295**	4.926	0.000	Supported
H3	SSCP →OPM	0.692**	9.677	0.000	Supported
H5	SSCP →Flexibility→Sustainability	0.726**	4.679	0.000	Supported
H6	SSCP→Flexibiliy →OPM	0.265**	3.276	0.000	Supported
H7	SSCP →flexibility	0.743**	15.381	0.000	Supported

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 Shericity 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); Cicculo 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; Yususf 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)

Construct	Domain	Author
Planning		
Order	The firm uses and order entry method that provides time specific and accurate	Gunasekaran et al. (2001);
	The firm strives to reduce the order lead-time	Ganeshan et al. (2001);
	The firm strives to reduce the order lead-time through having a well- integrated actions that are performed in	Fleisch and Tellkamp (2005);
	parallel by a cross-functional teams	Trkman et al. (2010);
	The firm strives to apply the order path (in order to eliminate non-value added activities, delays in paperwork's,	Jabbour et al. (2011);
	time spent in checking and re-checking)	Prajogo and Olhager (2012);
	The firm strives to forecast, predict and analyze markets trends of goods and services	Steinrücke and Jahr (2012);
	The frim strives to reduce the bullwhip effect	Katiyar et. al (2018)
	The firms strives to avoid extra cost and process inefficiencies	
	The firm strives to obtain sufficient information to avoid unnecessary stock and uncoordinated production	
	processes	
	The firm strives to communication the suppliers about future strategies	
	The firm strives to increase suppliers' just in time capabilities	
Tactical	The firm focus on tactical planning taking into consideration all related parts between strategic and operative	Ganeshan et al. (2001) ;
	planning	Jabbour et al. (2011);
	The firm set goals concerning production quantities and production deadlines	Steinrücke and Jahr (2012)
	The firm strives improve performance of the SCM as a whole by implementing a better quality forecast	
	The frim strives satisfy demand by creating a practical (feasible) plans	
	The firm strives to obtain high performances through the integration of all production sites provided by the	
	implementation of tactical planning	
	The firm strives to calculate the order quantities of intermediate and finished goods through applying the	
	material requirements planning	
	The firm pursues to hinder delays in deliveries	
	The firm pursues to guarantee the cost-effective organization of all processes	
	The firm aims to apply tactical planning in order to satisfy customer demand at minimal cost	
	The firm strives to determine quality teams	
	The firm strives to initiate the creation of multifunctional logistics	
	The firm strives to define customers' needs for the future	
	The firm strives to reduce the procurement cost that includes both the costs for manufacturing units of	
	intermediates products and the costs of producing units of finished products.	
	The firm strive to share information with supplier about launching a new product	
Inventory	The firm makes minimal forecast errors	Beamon (1999);
strategy	The firm has a low replanting frequency	Gunasekaran et al. (2001);
	The firm's communication facilities the exchange of useful information among all departments	Ganeshan et al. (2001) ;
	The firm strive to reduce cost associated with obsolete inventory (including spoilage)	Fleisch and Tellkamp (2005)
	The firm strive to reduce cost associated with work-in-process	Katiyar et. al (2018)
	The firm strive to reduce cost associated with held finished goods	
	The firm strives to reduce the services costs	
	The firm strives to control the cost associated with scrap and rework	
	The firm strives to reduce the cost associated with damage , pilferage or deterioration	
	The firm strives to determine the amount and the location of every raw materials	
	The firm strives to match the supply with customer's need/ demand	
	The firm strive to determine the distribution center which will serve each customer	
	The firm strives to collaborate with the suppliers regarding all Inventory aspects	
Sourcing		
Strategic	The firm strive to ensure that all order fills are on time	Worldbank (2016);
	The firm strive to ensure that supplier's growth plan matches the firm's future plans	Katiyar *et al.* (2018)
Tactical	The firm strive to ensure that suppliers have high ability to respond to quality problems	Trkman et al. (2010);
	The firm strive to offer mutual assistance in solving problems (with suppliers)	Prajogo and Olhager (2012);
	The firm ensure that suppliers have high capacity flexibility	Fleisch and Tellkamp (2005)
	The firm pursues to maintain long-term of partnership between buyer and seller	Katiyar et al. (2018)
	The firm strives to facilitate the procurement of goods and services	
	The firm strives to search , negotiate and evaluate agents in order to improve supplier selection , price	
	negotiation	
Operational	The firm strive to ensure to achieve a low inventory carrying cost	Worldbank (2016);
		Katiyar et al. (2018)
Make	The firm aims to achieve just-in-production	Beamon (1999);
	The firm strive to reduce lead time during production	Gunasekaran et al. (2001);
	The firm strive for correct production of each inventory item in terms of belt and batch	Trkman et al. (2010);
	The firm strive to reduce manufacturing cost	Jabbour et al. (2011);
	The firm strives to ensure that the amount of intermediate product from the suppliers is equal to the	Steinrücke and Jahr (2012);
	manufactured quantities	Katiyar et. al (2018)
	The firm strives to provide high quality of final products	
	The firm strives to decrease product cost at each stage of manufacturing (Labor and equipment)	
	The firm strive to efficiency and effectiveness by maintaining production in accordance with production	
	schedule	
Assembly	The firm strive for high effective scheduling techniques (flexibility)	Worldbank (2016);
	The firm strive for high efficiency in design for assembly	Katiyar et al. (2018)
	The firm produces a wide range of products and services (diversification)	
	The firm strive for high capacity utilization	
Packaging	The firm strives to reduce packaging cost	Ninlawan et al. (2010);
	The firm strives to use alternative packaging materials and techniques in order to reduce environmental impacts	Ganeshan et al. (2001) ;
		Fleisch and Tellkamp (2005)
	The firm strives to increase eco-friendly packaging	Cosimato and Troisi (2015)
	The firm strives to use flat packaging design related to storage space	
	The firm strives to reduce the storage space	
Delivery	The firm strive for flexibility to meet particular customer needs	Beamon (1999);
	The firm strive to reduce cost (delivery) of goods	Gunasekaran et al. (2001);
	The firm strive to reduce the number of fault notes invoice	Zhou and Benton (2007);
	The frim strive to increase the percentage of goods in transit	Trkman et al. (2010);
	The firm strive to improve the efficiency of the three constructs of SC practices i.e: SC planning , JIT production&	Jabbour et al. (2011);
	delivery practice	Steinrücke and Jahr (2012);
	The firm strives to reduce the shipping cost	Prajogo and Olhager (2012);
	The firm strives to generate less noise , air pollution and traffic crowding	Cosimato and Troisi (2015);
	The firm strives to increase green logistics activities	Katiyar et. al (2018)
	The firm strives to use effective shipments that are designed for chemicals and beverages sectors in order to	
	prevent any damage that might occur for liquids	
	The firm strives to reduce fuel consumption	
	The firm strives to ensure that the products delivered to the right customers and right product	
	The firm strives to choose the right delivery mode	
	The firm strives to reduce the environmental damage caused by the delivery phase	
	The firm strives to reduce the time of the delivered products from its suppliers	
	The firm strives to collaborate with suppliers and distributors in order to reduce the delivery cost	
	The firm strive to ensure that the customer receive on-time deliveries	
	The firm strives to response number of urgent deliveries	
	The firm strives to bring products to market more efficiently	
	The firm strives to use specific transportation modes between SC processes	
Return	The firm strives to decrease the cost of storing or managing the waste	Beamon (1999);
	The firm strives to adopt ISO 14000 series in order to enhance environmental performance	Ganeshan et al. (2001) ;
	The firm strives to recycle the products after separating them into categories	Fleisch and Tellkamp (2005)
	The firm strives to keep the quality of the material after recycling	Prajogo and Olhager (2012);
	The firm strives to emphasize on the re-manufacturing stage in order to not deteriorate the value of the	Cosimato and Troisi (2015)
	materials	
	The firm strives to increase the recovery of products	
	The firm strives to recycle up to 100% of raw materials	
	The firm strive to reduce the amount of waste disposal	
	The firm strives to return the product into its new condition	
	The firm strives to focus on the utilization of reusable packaging and shipping materials	
	The firm strives to recover any piece of any returned product that might contain value	
	The firms strives to repair , refurbish and overhaul an item	
	The firm strives to sell products/ materials/components that have been used (re-use)	

Appendix B: The Model constructs and their indicators

Latent variable/Construct		Indicator/manifest Variable	
Supply Chain Practices (SCP)			
Planning Performance	*Order Planning*	The firm uses and orders entry method that provides time specific and accurate infor	SCP1
		The firm strives to apply the order path (in order to eliminate non-value added activities, delays in paperwork's, time spent in checking and re-checking)	SCP2
		The firm strives to reduce the bullwhip effect	SCP3
		The firms strives to satisfy customer demand through highly efficient and cost-effective process in all stages of the supply chain	SCP4
		The firm's communication among all departments and with suppliers facilitates the ex	SCP5
		The firm strives to increase suppliers' just in time capabilities	SCP6
	Tactical Planning	The firm focus on tactical planning taking into consideration all related parts between	SCP7
		The firm strives to satisfy demand by creating practical (feasible) plans	SCP8
		production sites provided by the implementation of tactical planning	SCP9
		The firm strives to make accurate forecasts to align the order of materials, production, and customer demand	SCP10
		The firm strives to determine quality teams	SCP11
		The firm strives to initiate the creation of multifunctional logistics	SCP12
	Inventory Strategy	The firm has a low replanting frequency	SCP13
		The firm strives to determine the amount and the location of every raw materials	SCP14
		The firm strives to determine the distribution center which will serve each customer	SCP15
		The firm strives to collaborate with the suppliers regarding all Inventory aspects	SCP16
Sourcing Performance	*Strategic*	The firm strive to ensure that all order fills are on time	SCP17
		The firm strive to ensure that supplier's growth plan matches the firm's future plans	SCP18
	Tactical	The firm strive to offer mutual assistance in solving problems (with suppliers)	SCP19
		The firm ensure that suppliers have high capacity flexibility	SCP20
		The firm pursues to maintain long-term of partnership between buyer and seller	SCP21
		The firm strives to facilitate the procurement of goods and services	SCP22
		The firm strives to search , negotiate and evaluate agents in order to improve supplie	SCP23
	Operational	The firm strives to ensure to achieve a low inventory carrying cost	SCP24
Delivery Performance		The firm strives for flexibility to meet particular customer needs	SCP25
		The firm strives to reduce the number of fault notes invoice	SCP26
		The firm strives to increase the percentage of goods in transit	SCP27
		The firm strives to increase green logistics activities that minimize noise generation,	SCP28
		The firm strives to use effective shipments that are designed for chemicals and	SCP29
		The firm strives to ensure that the right products are delivered to the right customers	SCP30
		The firm strives to response number of urgent deliveries	SCP31
		The firm strives to bring products to market more efficiently	SCP32
		The firm strives to use specific transportation modes between SC processes	SCP33
Make		The firm aims to achieve just-in-production	SCP34
		The firm strive to reduce the overall lead time (through cross-functional teams)	SCP35
		The firm strive for correct production of each inventory item in terms of belt and bat	SCP36
		The firm strives to ensure that the amount of intermediate product from the suppliers	SCP37
		The firm strives to provide high quality of recycled materials and final products	SCP38
		The firm strive to efficiency and effectiveness by maintaining production in accordan	SCP39
Assembly		The firm strive for high effective scheduling techniques (flexibility)	SCP40
		The firm produces a wide range of products and services (diversification)	SCP41
		The firm strive for high capacity utilization	SCP42
Packaging		The firm strives to use packaging materials, design, and techniques in order to minimize the cost and environmental impacts	SCP43
		The firm strives to reduce packaging cost and storage space	SCP44
Return		The firm strives to adopt ISO 14000 series in order to enhance environmental perfo	SCP45
		The firm strives to emphasize on the re-manufacturing stage in order to not deteriora	SCP46
		packaging and shipping materials, and minimizing the amount of waste disposal	SCP47
		The firm strives to return the product into its new condition	SCP48
		The firm strives to recover, repair , refurbish, and re-sell used product/materials/con	SCP49
Flexibility Practices (Flexible Manufacturing systems)			
Necessary/operational		The system is able to switch operations with minimal effort	FMS1
		Different part types can be moved efficiently for proper positioning and processing	FMS2
		New parts can be added or substituted for the existing parts easily	FMS8
		The number of workers, tasks performed by workers, and responsibilities can be	FMS5
		A part can be produce by alternative routes	FMS7
Sufficient/Tactical		The system can produce a set of part types without major set-up	FMS6
		Parts can be produced in different ways with alternative process plans	FMS3
		The system can run virtually untended for a long enough period	FMS13
		Materials are easily transported to the manufacturing facility, and to operations	FMS10
Competitive/Strategic		The system can be operated profitably at different product overall output levels	FMS11
		Automation is capable of performing different operations and/or add operations	FMS4
		The system can easily produce a product with different shape and/or dimension	FMS9
		The system's capacity and capability can be easily increased when needed	FMS12
		The FMS system can produce a big variety of part types	FMS14
		The manufacturing system can easily adapt to a changing market environment	FMS15
Sustainability Performance Criteria			
Economic performance		Improved market share	SUSEC1
		Improved company image	SUSEC2
		Improve company's position in the market place	SUSEC3
		Increase profitability	SUSEC4
		Decrease in material purchasing cost	SUSEC5
		Decrease in utility bills	SUSEC6
		Decrease in waste treatment fees	SUSEC7
		Decrease in waste discharge fees	SUSEC8
		Reduction of environmental accident cases	SUSEC9
		Improved product quality	SUSEC10
Environmental performance		Reduce CO2 emissions	SUSEN1
		Reduction of wastewater	SUSEN2
		Reduction of solid wastes	SUSEN3
		Reduction of energy consumption	SUSEN4
		Decrease in production of toxic, hazardous, or harmful substances	SUSEN5
		Decrease in material usage	SUSEN6
		Improved compliance with environmental standards	SUSEN7
Social performance		The firm has very good relations with the community and stakeholders	SUSSC1
		Work in the firm is safe	SUSSC2
		Employee health and safety (Improvement)	SUSSC3
		Work environment (Improvement)	SUSSC4
		Improve the living quality of surrounding community	SUSSC5
		The firm takes social welfare initiatives	SUSSC6
		The firm complies with laws and standards	SUSSC7
		The firm highly respects human rights	SUSSC8
		The firm has good working conditions	SUSSC9
		The firm treats suppliers fairly	SUSSC10
		The firm ensures product safety	SUSSC11
Operational Performance Metrics (OPM)			
Reducing operational/Manufacturing Cost		Cost	OPM1
Improving product quality		Quality	OPM2
Improving product delivery		Delivery	OPM3
Improving manufacturing productivity		Efficiency and Productivity	OPM4
Improving employee safety		Safety	OPM5

Appendix C: Correlation metrics

		CR	Planning	Sourcing	Delivery	Make	Assembly	Packing	Return	Necessary	Sufficient	Competitive	Economi	Environmental	Social	OPM
Supply Chain Performance	Planning	0.887	1													
	Sourcing	0.821	.928**	1												
	Delivery	0.843	.876**	.879**	1											
	Make	0.81	.884**	.816**	.878**	1										
	Assembly	0.884	.827**	.798**	.812**	.868**	1									
	Packing	0.81	.788**	.702**	.790**	.761**	.875**	1								
	Return	0.745	.669**	.785**	.828**	.698**	.771**	.842**	1							
Flexibility Performance	Necessary	0.942	.768**	.640**	.670**	.720**	.650**	.594**	.764**	1						
	Sufficient	0.904	.755**	.613**	.670**	.721**	.660**	.597**	.518**	.912**	1					
	Competitive	0.883	.721**	.563**	.631**	.686**	.623**	.628**	.497**	.841**	.887**	1				
Sustainability Performance	Economic	0.945	.838**	.682**	.744**	.810**	.718**	.672**	.594**	.906**	.862**	.888**	1			
	Environmental	0.944	.815**	.713**	.782**	.797**	.743**	.713**	.645**	.875**	.855**	.857**	.910**	1		
	Social	0.921	.824**	.687**	.754**	.792**	.726**	.737**	.595**	.861**	.863**	.868**	.893**	.915**	1	
	OPM	0.813	.850**	.783**	.839**	.837**	.808**	.794**	.732**	.751**	.760**	.713**	.793**	.819**	.788**	1

**. Correlation is significant at the 0.01 level (2-tailed).

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Biography

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