



# A Self-Assessment Framework for Global Supply Chain Operations: Case Study of a Machine Tool Manufacturer

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## ABSTRACT

This research developed an effective supply chain management (SCM) operation model and a corresponding diagnostic methodology in the global competitive environment by combining three phases and methodologies. In Phase 1, a list of impact factors was collected from relevant studies, and a hierarchy for the current complex research issue was established. In Phase 2, an expert survey was conducted for enhancing the content effectiveness of the model. Subsequently, an analytic hierarchy process (AHP) was applied to determine the weights of those factors. In Phase 3, a self-assessment framework was developed to examine the effectiveness of the global SCM. Finally, a case was analyzed to verify the effectiveness of the self-assessment scales. The results show that the concept of global SCM tends to be broader and more comprehensive than the traditional one, especially in the coordination and cooperation between market, organization itself, and suppliers while using information technology as a communication tool.

## KEYWORDS

Global Operations Management, Performance Measurement, Small and Medium-Sized Enterprises, Supply Chain Diagnostic Methodologies, Supply Chain Management

## INTRODUCTION

The US–Sino trade dispute has escalated to become a competition for global hegemony. Many countries have moved their manufacturing factories back to their own country, and have emphasized more on the local production ratio of components in a commodity. For example, China's local production requirements for Tesla vehicles, India's local production requirements for mobile phone assembly and battery supply, etc. The dispute is not a simple trade issue; it involves science and technology as well as geopolitics (Kim, 2019; Wojczewski, 2019). Moreover, affected by the COVID-19 epidemic, companies have re-examined risk management, accelerated the establishment of diversified production

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bases (cross-regional, cross-country). Especially, due to the difference in the severity of the epidemic among countries and the difference in the date of the outbreak, the timing of shutdowns or shortages of workers is different in factories around the world. This has led to a decline in the output rate of the global supply chain in the division of production across regions. These facts show that the severity and frequency of supply chain outages have been increasing. As a result, the order transferring effect and the vertical integration of the production chain (avoiding chain breaks caused by outbreak blockades in other countries) in the supply chain are happening frequently.

In the short term, it will affect capital markets. In the long term, it will change the supply chain ecology and the global trade order (Freund, Ferrantino, Maliszewska, & Ruta, 2018; Kim, 2019). For example, East Asia is the main source of global manufacturing. Among them, Taiwan's imports from mainland China are mainly electronic components and mechanical parts, and many imported products come from mainland China as the first source country. During the epidemic, the manufacturing industry has planned to move back to Taiwan with higher value-added and automated processes. However, industries such as machinery and petrochemicals that take the mainland as their main export market are also actively seeking other emerging markets. In response to competition in international manufacturing, vertical integration between partner industries has become an inevitable trend. The most obvious typical transformation for modern business management is that businesses are not only competing against each other, but also competing in the supply chain (Ellram, Tate, & Feitzinger, 2013; Poluha, 2016).

Enhancing production capability and accuracy are key concerns of industries with a focus on precision manufacturing and technology, such as industry 4.0 (Dornfeld, 2014; Zheng et al., 2018). These concerns are critical to the machine tool industry, which is the foundation for industrial development in a country, and plays a key role in the development of a variety of consumer electronics (Xu, 2017). Taiwan's machine tool industry is highly competitive in its pursuit of accuracy and effective cost control (Hung, Chang, Hung, Yen, & Chou, 2016). It is characterized by tight supply chain relationships, high interdependence, high added value in the industry, and high overall efficiency, and is, therefore, plays a role in the global machine tool supply chain system (Chen, 2018; Chen, 2011). In the face of current global competition, it is necessary to re-evaluate and adjust the supply chain operating model. Therefore, how to effectively improve global supply chain operation management is a crucial issue given the globalized competition from major international manufacturers.

With the development of the concept of global supply chain management, it can let companies know which suppliers, corporate websites, components, and products may face supply chain risks. Therefore, companies must seriously consider the risk management of global supply chain operations and value chains, and simultaneously make trade-offs between opportunities and risks. For example, companies can use digital supply networks to eliminate communication barriers between various departments within the company, allowing them to seamlessly connect with the supply chain operations to improve visibility and agility, thereby reducing the impact of global crises on their supply chains. To comprehensively describe all aspects of the supply chain and help companies better implement an effective supply chain, Pittiglio Rabin Todd & McGrath and Advanced Market Research consulting companies proposed the Supply Chain Operation Reference Model (SCOR) in 1996 (Ashayeri, Tuzkaya, & Tuzkaya, 2012; Stephens, 1999). Benchmarkable supply chain performance can be measured using a SCOR based approach (Kocaoğlu, Gülsün, & Tanyaş, 2013). However, more than two decades have passed. We are beginning to wonder whether the SCOR model meet the challenges of today's supply chain globalization? It is urgent to think through an updated reference model and further develop a tool that allows companies to self-diagnose their supply chain operations.

Previous studies indicate a significant gap between theoretically important supply chain management tools and ideas and the reality of organizations' operations (Copacino, 2019; Taticchi, Garengo, Nudurupati, Tonelli, & Pasqualino, 2015). In addition, good tools might minimize the risks and maximize the benefits of the whole supply chain (Ada, Sagnak, Kazancoglu, Luthra, & Kumar, 2021; Gattorna, 2017). Gadiesh and Gilbert (1998) proposed a profit pool mapping technique and

Towill (1999) developed a toolbox approach with a best practice database. Childerhouse and Towill (2011) proposed a systematic approach called Quick Scan Audit Methodology (QSAM), which is designed to conduct a supply chain-oriented diagnostic health check of a business. Despite the increasing research interest in SCM, there is still a lack of academic literature concerning topics of relevance to SCM management theories.

Studies also indicate a significant gap between large organizations and SMEs with respect to implementing tools that include a supply chain management concept (Quayle, 2003). For instance, QSAM typically needs a team of four researchers and a week is needed to fully audit the supply chain of a medium-sized organization (Aitken, Childerhouse, Deakins, & Towill, 2016), which is not affordable or reasonable for an SME. Specific research questions are as follows.

RQ1: Whether the SCOR model can meet the challenges of today's supply chain globalization?

RQ2: What are the benefits, and key success factors of a global supply chain operation model?

RQ3: Whether standardized methods and tools for self-diagnosis are sufficient to run into the specific realities of global supply chain operations?

To answer these questions, we conduct the current study to discover and develop an effective SCM operation model and corresponding diagnostic methodology for machine tool SMEs in a globally competitive environment. The study particularly focuses on SCM practices in SMEs in Taiwan's machine tool industry and how to establish a global SCM operation model. It is hoped that it will help the machine tool industry increase SCM performance globally. The methodology provides a framework for analyzing global SCM, which contributes to management theory and provides explanations for practical applications of the theoretical recommendations.

The remainder of the paper is in four parts. The first is a review of prior related literature. Then, based on the literature, a model is proposed that is then further developed based on a series of surveys and interviews. The final part of the paper presents conclusions and recommendations.

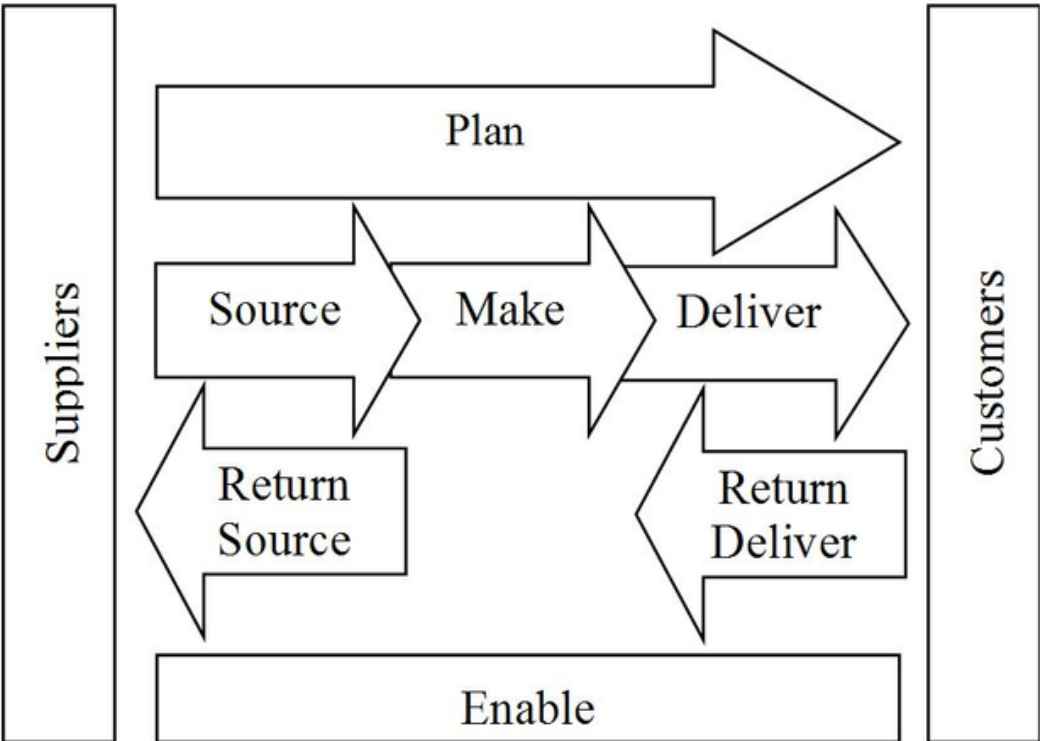
## **Literature Review**

### **Theoretical Underpinning**

The SCOR is a systematic supply chain operation model and a renowned reference guide in real business practice (Huan, Sheoran, & Wang, 2004b; Stephens, 1999). It is widely adopted by major companies around the world (Kottala & Herbert, 2019). SCOR allows supply chain partners to communicate more effectively, and it can also be used to describe, measure, and assess a supply chain's structure (Huan, Sheoran, & Wang, 2004a; Li, Su, & Chen, 2011; Sellitto, Pereira, Borchardt, da Silva, & Viegas, 2015). According to SCOR, a supply chain process can be divided into five major categories: plan, source, make, deliver, return, which are explained as follows (as shown in Figure 1). Plan, to balance demand and resources and establish a management plan for the entire supply chain, coordinating supply chain planning with financial planning. Source, this includes inventory purchased from suppliers or manufactured ready for distribution, goods manufactured on customers' orders, and goods manufactured according to customer product design and specifications to schedule distribution. Make, produce, test, package, and store inventory and distribute goods when they are distributed. Deliver, management of shipping instructions, delivery, packaging, transportation, and distribution of goods and retail goods through different manufacturing processes. Return, goods to be identified and returned for return, including damaged, repairable and remaining items. The first tier of the model includes processes for these highest levels. The process units in the model allow companies to use the same language and definitions to communicate more easily whether the supply chain is straightforward or extremely complicated. SCOR also provides a map for initiating supply chain improvement projects at both global and regional scales. Thus, the operations of the whole supply chain can be better linked together and achieve higher performance (Lima-Junior & Carpinetti,

2019; Zhou, Benton Jr, Schilling, & Milligan, 2011). As a result, the implementation of SCM can enable suppliers, manufactories, and customers to turn what was originally a hostile relationship into a strategic alliance and long-term collaboration.

Figure 1. The Major Category Management Processes of the SCOR Model



Numerous key successful factors for global supply chain operation are proposed in the literature (Chow, 2004), and they can be merged into five high-level factors. Factor one is utilizing information technology to enhance business efficiency and effectiveness. Numerous companies have increased their value through outsourcing and the practice of “virtual enterprise”. This shows the importance of utilizing information technology to integrate suppliers and partner companies in a supply chain (Dhar & Balakrishnan, 2006; Gunasekaran & Ngai, 2004; Liu, Wei, Ke, Wei, & Hua, 2016; Uniyal, Mangla, Sarma, Tseng, & Patil, 2021). In the face of global competition, effective use of information technology can make communication between and within a business more efficient and further enhance business effectiveness (Tseng & Liao, 2015; Yenyurt, Wu, Kim, & Cavusgil, 2019).

Factor two is the strong coordination and integration of processes among businesses. Businesses need to integrate information systems with business processes to support operations and coordination between businesses and with suppliers based on modularized processes and structured data (Grover & Saeed, 2007; Movahedi, Miri-Lavassani, & Kumar, 2016; Seth, Goyal, & Kiran, 2017). Such coordination and integration with suppliers can enhance supply chain transparency and flexibility (Fayezi, Zutshi, & O’Loughlin, 2017; Gosain, Malhotra, & El Sawy, 2004).

Factor three is maintaining flexibility to meet market demands. A business must link up with its supply chain partners so that it can respond to changes in the business environment (Fayezi et al.,

2017; Gosain et al., 2004; Jain, Kumar, Soni, & Chandra, 2017). Flexible operation processes can significantly enhance a company's SCM ability and enable it to gain a competitive edge (Srinivasan & Swink, 2018; Tiwari, Tiwari, & Samuel, 2015; Tracey, Lim, & Vonderembse, 2005).

Factor four is seeking outsourced resources on a low-cost basis. To survive in mature regional markets, businesses need to look for external resources for cheaper production (Jazairy, Lenhardt, & von Haartman, 2017; Scott, Lundgren, & Thompson, 2011; Williamson, 2008). This is a strategy commonly adopted by businesses that want to reduce operating costs (Globerman & Vining, 2017; Williamson, 2008).

Factor five is creating strategic alliances to expand market share. It has been reported that the primary factors for a successful supply chain are the effective management of strategic alliances (Yang, Lai, Wang, Rauniar, & Xie, 2015) and excellent information management capability and advanced information systems among organizations to ensure better information exchange (Liu, Zhang, & Hu, 2005; Song, Yu, Ganguly, & Turson, 2016). As a result, the implementation of SCM can enable logistics providers, suppliers, and customers to turn what was originally a hostile relationship into a strategic alliance and long-term collaboration (Klaas-Wissing & Albers, 2010; Yang et al., 2015).

### **Supply Chain Audit and Diagnostic Methodologies**

Supply chain management integrates key business processes among industry partners, adds value to customers, and closely links several continuous elements of the industry supply chain, from upstream suppliers to component manufacturers, and then to the final manufacturer (Arend & Wisner, 2005). However, with the drastic changes in the global industrial environment, manufacturers may face huge supply chain management challenges and limit their ability to increase production scale. The concept of supply chain audit and diagnostic methodology was originally used to diagnose the health of an individual supply chain (Banomyong et al., 2005). By creating a set of unified and coded performance attributes, the distribution of effectiveness attributes of any company in the competitive value chain can be evaluated (Boehme et al., 2007).

Relatively few methodologies for the analysis of supply chain operations are included in the literature. Gadiesh and Gilbert (1998) propose a four-step technique, called profit pool mapping, to analyze how profits are distributed among the various activities and identify where the margin in an industry's value chain is generated. Such a technique can provide a company's managers with an understanding of their industry's profit structure. However, it concentrates on activities that add profit and does not provide a comprehensive view of the up/middle/downstream of the entire supply chain. Towill (1999) developed a toolbox with a best practice database, sample worksheets, and an implementation methodology, with the aim of integrating the outputs of experts, consultants, academics, and practicing managers.

Extending the concept of audit and diagnostic methodology, Childerhouse (1999) proposed a systematic approach called quick scan audit methodology (QSAM), which is used for evaluating the operating characteristics and performance of specific value streams. QSAM presents a guide for conducting supply chain-oriented business diagnostics or a health check termed a "quick scan," and it can be an initial step in a generic SCM diagnostic methodology (Childerhouse & Towill, 2011).

In contrast to the methodologies proposed by consultants, academic researchers have suggested a methodology for evaluating companies' degree of adherence to an SCM conceptual model to contribute to SCM theory development (Simon, Serio, Pires, & Martins, 2015). Furthermore, using this methodology, businesses can identify and implement activities to improve the degree of adherence to the conceptual model and achieve SCM benefits (Simon et al., 2015). Despite the increasing interest from researchers in SCM performance measurement (Kocaoğlu et al., 2013; Sellitto et al., 2015), there is still a lack of academic literature concerning topics such as methodologies to guide and support SCM evaluation, such as digitization and globalization of supply chain management.

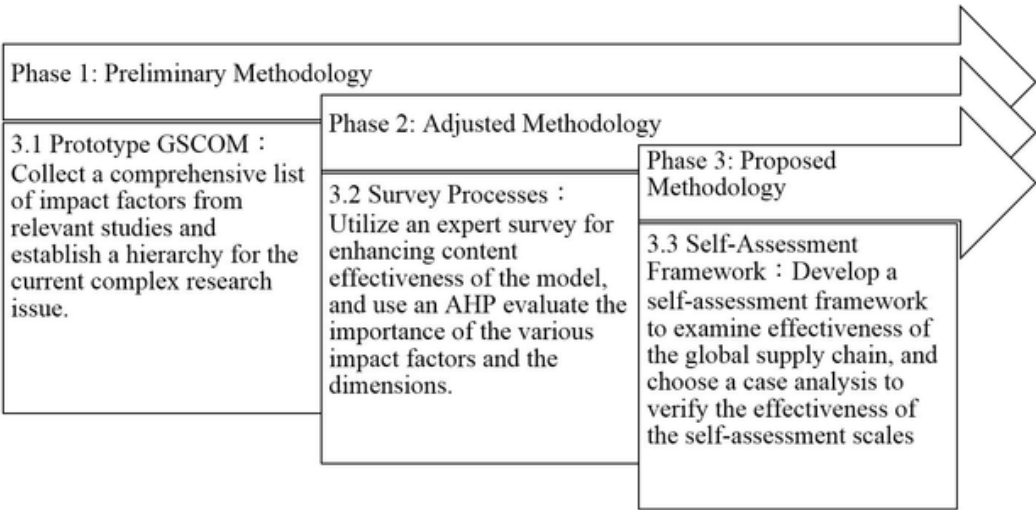
## Research Methodology

The approach used in this work combines three different phases and methodologies as shown in Figure 2. In Phase 1, relevant studies were reviewed to collect a comprehensive list of factors that may affect the success of the global supply chain and to establish a hierarchy for the current complex research issue.

In Phase 2, a survey of experts was conducted to enhance the content effectiveness of the model. Groups of professionals, both academics and practitioners, were invited to take part based on their expertise in SCM. An analytic hierarchy process (AHP) was used to determine the weights and rankings of the identified impact factors, with the aim of evaluating the importance of the various factors and dimensions.

In Phase 3, after adjusting constructs and terminologies to match academic and managerial usage, we developed a self-assessment framework to examine the effectiveness of the global supply chain. Scores on the self-assessment framework were then obtained from a comparison of data between now and a specific point of time in the past. Finally, a case analysis was used to verify the effectiveness of the self-assessment scales. The following three subsections describe the three stages in details.

Figure 2. Stages of Methodology Development



### Prototype Global Supply Chain Operation Model (Phase 1)

Several prior studies of machine tool industry characteristics, SCOR model applications, and SCM self-assessment methodologies were reviewed to develop a prototype global supply chain operation model (GSCOM) consisting of eight dimensions (supplier, purchasing, manufacturing, shipping, market, planning, information technology, and organizational integration). Definitions of the eight dimensions are presented in Table 1. After dimension selection, 44 measurement items were selected based on the literature (see Table 2)

Table 1. Definition of research dimensions

Dimension	Definition
<b>Supplier</b>	Suppliers provide businesses with raw materials. Interactions and relationships established with suppliers will affect business performance (Stephens, 1999).
<b>Purchasing</b>	Businesses purchase raw materials from suppliers, influenced by management mechanisms (Jazairy et al., 2017; Stephens, 1999).
<b>Manufacturing</b>	Businesses generate products through the processes of production, testing, and packaging (Stephens, 1999).
<b>Shipping</b>	The management of the whole process of delivery, sorting, packaging, and final delivery of finished products (Stephens, 1999).
<b>Market</b>	A group of consumers who have needs for a business's products. A market also comprises the target buyers for the business's product. It is affected by competitive rivals and social issues (Gosain et al., 2004; Liu et al., 2005).
<b>Planning</b>	Businesses establish a management plan for the entire supply chain, balance needs, and resources, and coordinate supply chain plans with financial plans (Stephens, 1999).
<b>Information Technology</b>	Businesses utilize information technologies to manage and disseminate information to achieve strategic goals (Gunasekaran & Ngai, 2004; Uniyal et al., 2021).
<b>Organizational Integration</b>	The coordinated relationship between organizational internal operational mechanisms and the external environment (Bi, Davidson, Kam, & Smyrniotis, 2013; Grover & Saeed, 2007).

Source: This study

## Two Survey Processes (Phase 2)

In order to decide the weights of various variables for the global SCM operation model in the SMEs machine tool industry, this research adopted the Analytic Hierarchy Process (AHP), a decision-making method developed by renowned US research expert Thomas Saaty in 1971 (Saaty, 1980), as a research method. The AHP has become the most common decision-making tool in decision-making. It is used to identify the relevant processes and select a target for supply chain redesign (Palma-Mendoza, 2014) and to assess supply chains (Dong & Cooper, 2016; Wang, Zhang, Chong, & Wang, 2017).

This research initially constructed the hierarchical structure of the global supply chain operation model for SMEs through an expert survey. By issuing AHP questionnaires, this study obtained the important result of pairwise comparisons concerning various impact factors from every industry expert. Afterward, this study collected and analyzed all expert surveys to obtain the relative weight of each impact factor. The relative weight of each impact factor obtained in this study is served as the basis for calculating the scores within the self-assessment framework.

The survey process for this study was divided into two parts: an expert survey and a business survey. First, expert opinions from academia and industry were obtained on the measurement dimensions and items in the model. A business survey was then conducted to collect opinions from the industry and the operating model was then modified accordingly. This process improved the reliability, validity, and practicality of this research.

## Self-Assessment Framework (Phase 3)

In the prototype development process, the weights of the measurement items for each dimension at two-time points (past and present) were compared. This was conducted in two stages to examine the effectiveness of the scale. The first stage was a collection of internal materials and interviews with senior managers to analyze the health of a supply chain at a specific point in time. In the next stage, a self-assessment framework was filled in by the senior managers. Scores on the self-assessment framework were then obtained from the comparison of data for the present time and a specific time

**Table 2. Measurement Items**

<b>Dimension</b>	<b>Measurement Items (Reference)</b>
<b>Supplier</b>	<ol style="list-style-type: none"> <li>1. Selection and Assessment of Suppliers (Fallahpour, Olugu, Musa, Wong, &amp; Noori, 2017; Kannan &amp; Tan, 2002);</li> <li>2. Close Collaboration with Suppliers (Hudnurkar &amp; Rathod, 2017);</li> <li>3. Bilateral Beneficial Information and Knowledge (Luo, Wu, Rosenberg, &amp; Barnes, 2009);</li> <li>4. Integration and Strategic Alliance with Supplier (Fynes, Coughlan, von Haartman, &amp; Bengtsson, 2015; Paulraj, Chen, &amp; Flynn, 2006; Schadel, Lockström, Moser, &amp; Harrison, 2016)</li> </ol>
<b>Purchasing</b>	<ol style="list-style-type: none"> <li>1. Reaching of Economies of Scale in Purchasing (Rodríguez &amp; Vecchietti, 2009);</li> <li>2. Transparency in Purchasing Price (Purchase, Goh, &amp; Dooley, 2009);</li> <li>3. Centralized Purchasing on Key Raw Materials (Ou, Chang, &amp; Lee, 2006);</li> <li>4. Drafting of Purchasing Policy (Ou et al., 2006)</li> <li>5. Control over Material and Inventory (Ohshima, 2003)</li> </ol>
<b>Manufacturing</b>	<ol style="list-style-type: none"> <li>1. Control of Key Raw Materials (Dewulf et al., 2015);</li> <li>2. Hiring Technical Manpower (Kaufmann &amp; Tödtling, 2002);</li> <li>3. Coordinated Manufacturing Capability (Tan, Smith, &amp; Saad, 2006);</li> <li>4. International Standard Quality Management Process (Ou et al., 2006; Rungtusanatham, 2001);</li> <li>5. Design and Improvement of Product Development (Rungtusanatham, 2001);</li> <li>6. Product Differentiation (Alizon, Shooter, &amp; Simpson, 2009)</li> </ol>
<b>Shipping</b>	<ol style="list-style-type: none"> <li>1. Establishment of Effective Shipping Mode (Elimam &amp; Dodin, 2013; Inman &amp; Blumenfeld, 2014; Sheu, 2008);</li> <li>2. Centralized Control over Global Logistics Movement (Ding &amp; Kaminsky, 2019; Nair*, 2005; Sheu, 2008);</li> <li>3. Coordination of Distribution Management (Ding &amp; Kaminsky, 2019; Rushton, Croucher, &amp; Baker, 2014; Sheu, 2008; Tsiakis &amp; Papageorgiou, 2008)</li> </ol>
<b>Market</b>	<ol style="list-style-type: none"> <li>1. Collection of Respective Market Information and Analysis of Market Trends (Ghaderi, Azadeh, Nokhandan, &amp; Fathi, 2012);</li> <li>2. Assessment and Mastery of Information about Competitor's Quality, Price and Service (Motade, Toloie-Eshlaghy, &amp; Halvachi-Zadeh, 2011);</li> <li>3. Excellent Marketing Capability (Lee, Lee, Peng, &amp; Cho, 2011);</li> <li>4. Customer Relationship Management Enhancement (Chang, Park, &amp; Chaui, 2010);</li> <li>5. Influence of Regulatory Policy (Ou et al., 2006);</li> <li>6. Emphasis over Safety and Environmental Issues (Ou et al., 2006)</li> </ol>
<b>Planning</b>	<ol style="list-style-type: none"> <li>1. Outsourcing of Partial Operation and Centralizing Core Business Activities (Al-Qirim, 2003; Ou et al., 2006);</li> <li>2. Simplify Process and Lower Cost (Ohshima, 2003);</li> <li>3. Inventory Management Improvement (Lin, Liang, &amp; Zhu, 2018; Ou et al., 2006);</li> <li>4. Operation Process Management Improvement (Chopra &amp; Meindl, 2001; Fragnière, Gondzio, &amp; Yang, 2010);</li> <li>5. Appropriate Utilization and Cultivation of Human Resources (Chopra &amp; Meindl, 2001);</li> <li>6. Independent Capability for Strategic Planning (Chopra &amp; Meindl, 2001; Ou et al., 2006);</li> <li>7. Centralized Coordination of Management and Planning over Global Business Resources (Bradley, 2008)</li> </ol>
<b>Information Technology</b>	<ol style="list-style-type: none"> <li>1. Basic Internet Application (Chou, Tan, &amp; Yen, 2004; Lancioni, Schau, &amp; Smith, 2003);</li> <li>2. Complete and Rigorous Design of Information System Software and Hardware (Chengalur-Smith, Duchessi, &amp; Gil-Garcia, 2012; Seth et al., 2017);</li> <li>3. Adopting the Electronic System (Chengalur-Smith et al., 2012);</li> <li>4. Standardization over Programming Language and Communication Protocol (Chengalur-Smith et al., 2012; Ou et al., 2006);</li> <li>5. Integration and Maintenance of the Platform among Businesses (Al-Qirim, 2003; Gunasekaran &amp; Ngai, 2004);</li> <li>6. Capabilities of Information Integration, Sharing, and Communication (Al-Qirim, 2003; Wong, Lai, &amp; Benroider, 2015);</li> <li>7. Digitalization of Industry Value Chain (Al-Qirim, 2003; Ou et al., 2006)</li> </ol>
<b>Organizational Integration</b>	<ol style="list-style-type: none"> <li>1. Achievement of Organization Learning and Knowledge (Dawes, Lee, &amp; Midgley, 2007; Ou et al., 2006);</li> <li>2. Up/Middle/Down Stream Supply Chain Integration (Paulraj et al., 2006);</li> <li>3. Up/Middle/Down Stream Supply Chain Strategic Alliance (Ou et al., 2006; Paul, Semeijn, &amp; Ernstson, 2010);</li> <li>4. Enhancement and Speeding-Up of Communication Transparency (Ou et al., 2006; Purchase et al., 2009);</li> <li>5. Enhancement of Coordination and Collaboration among Supply Chain Members (Bradley, Meyer, &amp; Gao, 2006; Ou et al., 2006);</li> <li>6. Industry Cluster/Network Pattern (Çelebi &amp; Bayraktar, 2008; Ou et al., 2006)</li> </ol>

Source: This study



in the past. The results of both stages were then compared. The self-assessment process is valid only if the two scores are similar.

## Self-Assessment Framework Refinement

### Expert Survey

Based on the literature, 44 critical influential factors were included in the proposed self-assessment framework. Those factors were classified into eight dimensions, and an expert questionnaire was designed based on the factors and dimensions. The research methodology proposed by Lawshe (1975) was used to verify the self-assessment framework. First, experts' opinions were collected through surveys of experts from academic institutions and machine tools industries. Second, the content validity rate (CVR) of each factor was calculated in order to ensure the content validity of each dimension. And then, screening CVR values to determine a self-assessment framework suitable for the machine tool industry.

The respondents to the expert survey were experts or scholars in the machine tools industry and senior consultants for the machine tools and information industry. The twelve expert interviewees were employed, including 4 professors from the academic field (2 for business school, the other 2 from college of engineering), 4 senior consultants from consulting companies, and 4 top managers from different machine tool companies, and had 15-30 years of experience about supply chain operations. Detailed information is shown in Table 3. The survey was conducted via e-mail. Experts were able to respond directly by e-mail after filling in the questionnaires. A CVR value of 0.58 was adopted as a threshold to filter out factors due to the number of respondents (Lawshe, 1975). The result is shown in Table 4.

Table 3. Interviewee list

Categories	Position title	expertise	Seniority
<b>Academic</b>	Professor, department chair.	Supply chain management, information management, software design.	15~20 years
<b>Consulting companies</b>	Senior consultant	Mechanical Engineering, manufacturing, information technology, industrial productivity.	20~25 years
<b>Top managers</b>	General manager, duty manager, factor manager	Machine tools manufacturing, Troubleshooting, Communications between departments	20~30 years

Source: This study

In the supplier dimension, all experts agreed with the importance of other factors in addition to “mutual benefit of information and knowledge (Su3)”. Every factor in the purchasing dimension received unanimous confirmation from experts. In the manufacturing dimension, experts did not think that “coordinated manufacturing capability (Mf3)” or “differentiated product (Mf6)” has a great influence on the success of a global supply chain. Product precision was unanimously considered by industrial experts to have relatively greater influence. In the shipping dimension, only “establishment of efficient transportation pattern (Sh1)” was unanimously considered by experts as an influential factor. For the other two factors shipping factors, “centralized control over global logistics (Sh2)” and “logistics distribution management (Sh3),” academic experts had different views from industrial consultants. This may be one of the few cases in which differences exist between real-world practices and academic theories.

Table 4. Results of the Expert Survey

Dimension	Item number	Sample size	CVR value (Industry experts)	CVR value (Consultant)	CVR value (Academic experts)	CVR value (All experts)	Filter
Supplier	Su1	12	1.00	0.75	1.00	0.92	Yes
	Su2	12	0.75	1.00	1.00	0.92	Yes
	Su3	12	0.75	0.50	0.00	0.42	No
	Su4	12	1.00	0.75	1.00	0.92	Yes
Purchasing	Pu1	12	0.75	0.50	0.50	0.58	Yes
	Pu2	12	0.50	1.00	0.50	0.67	Yes
	Pu3	12	0.50	0.75	0.75	0.67	Yes
	Pu4	12	0.75	0.75	0.50	0.67	Yes
	Pu5	12	1.00	0.25	0.75	0.67	Yes
Manufacturing	Mf1	12	1.00	0.75	1.00	0.92	Yes
	Mf2	12	1.00	0.75	0.75	0.83	Yes
	Mf3	12	0.50	0.50	0.25	0.42	No
	Mf4	12	1.00	0.75	0.75	0.83	Yes
	Mf5	12	1.00	0.25	0.75	0.67	Yes
	Mf6	12	0.50	0.50	0.50	0.50	No
Shipping	Sh1	12	0.75	1.00	0.50	0.75	Yes
	Sh2	12	0.00	0.75	0.50	0.42	No
	Sh3	12	0.00	0.50	0.75	0.42	No
Market	Mk1	12	1.00	0.25	1.00	0.75	Yes
	Mk2	12	0.75	0.50	1.00	0.75	Yes
	Mk3	12	0.50	0.50	0.75	0.58	Yes
	Mk4	12	1.00	0.75	0.50	0.75	Yes
	Mk5	12	1.00	0.25	0.25	0.50	No
	Mk6	12	0.75	0.25	0.50	0.50	No
Planning	Pl1	12	0.50	0.25	0.25	0.33	No
	Pl2	12	1.00	1.00	0.75	0.92	Yes
	Pl3	12	1.00	0.75	0.50	0.75	Yes
	Pl4	12	0.75	0.50	0.50	0.58	Yes
	Pl5	12	1.00	0.75	0.75	0.83	Yes
	Pl6	12	1.00	0.50	0.75	0.75	Yes
	Pl7	12	0.50	0.25	0.50	0.42	No
Information Technology	IT1	12	0.75	0.75	0.75	0.75	Yes
	IT2	12	1.00	0.75	1.00	0.92	Yes
	IT3	12	0.75	0.75	0.75	0.75	Yes
	IT4	12	0.75	0.75	0.50	0.67	Yes
	IT5	12	0.75	0.50	0.75	0.67	Yes
	IT6	12	0.75	0.75	0.75	0.75	Yes
	IT7	12	0.25	0.25	0.50	0.33	No

*continued on next page*

Table 4. Continued

Dimension	Item number	Sample size	CVR value (Industry experts)	CVR value (Consultant)	CVR value (Academic experts)	CVR value (All experts)	Filter
Organizational integration	Or1	12	0.25	0.75	0.25	0.42	No
	Or2	12	0.50	0.75	1.00	0.75	Yes
	Or3	12	1.00	0.50	0.50	0.67	Yes
	Or4	12	0.75	0.75	1.00	0.83	Yes
	Or5	12	0.75	0.75	0.75	0.75	Yes
	Or6	12	1.00	0.75	0.50	0.75	Yes

Source: This study

In the market dimension, “influence of regulatory policy (Mk5)” and “emphasis on safety and environmental issues (Mk6)” were not considered to be critical by the experts. In the planning dimension, the experts had inconsistent views on “outsourcing of partial operation and centralizing core business activities (Pl1)” and “centralized coordination of management and planning over global business resources (Pl7).” Not all experts agreed that they were important factors. In the information technology dimension, both industry and consulting experts considered “digitalization of the industry value chain (IT7)” to be less influential in the supply chain. Finally, in the organizational integration dimension, all experts shared opinions about numerous factors. However, on “achievement of organizational learning and knowledge (Or1),” there were great differences between consultants’ opinions and those of industry experts or scholars.

After ascertaining the experts’ opinions, we removed 11 factors that experts do not consider to be key.

The final assessment framework included a total of 33 key factors.

## AHP Questionnaire

AHP was used to establish the weights for various items in the assessment framework. First, the results from the expert survey were used to establish the layer structure for the assessment framework, and an AHP questionnaire was then designed accordingly. The AHP questionnaires were then distributed to senior executives in the industry to enable a pairwise comparison of the relative importance of each factor. Then, the survey results were collected and the weight of each factor was calculated. The weight of each factor was used as the basis for the score on the assessment framework (see Appendix 1). Respondents to the AHP questionnaire were senior managers from machine tool SMEs. The questionnaire was distributed via e-mail. A total of 31 copies were retrieved. After analysis using “Expert Choice” software, 25 were considered valid based on the consistency of their answers. Finally, the geometric average method was used to calculate the weight of each factor in the 25 valid questionnaires and examine the consistency of the entire AHP layer structure.

The importance of each factor in each aspect derived from the opinions of senior managers in machine tool SMEs are shown in Appendix 2. In the supplier’s aspect, “The degree of close collaboration with suppliers (C12)” had the highest priority value. In the purchasing aspect, “The ability to control material and inventory (C25)” had the highest priority value. In the manufacturing aspect, “The ability to design and improve product development (C34)” had the highest priority value. In the shipping aspect, “The degree of establishment of effective shipping mode (C41)” had the highest priority value. In the market aspect, “The degree of customer relationship management enhancement (C54)” had the highest priority value. In the planning aspect, “The ability to improve inventory management (C62)” had the highest priority value. In the information technology aspect, “The degree of capabilities of information integration, sharing and communication (C76)” had the

highest priority value. In the organizational aspect, “The degree of enhancement and speeded up on communication transparency (C83)” had the highest priority value.

This study integrates the weights of elements in each layer to calculate the total priority of that layer. Overall, the factor “The degree of customer relationship management enhancement (C54)” in the market dimension is the most important factor to senior managers in the machine tool industry.

## Testing the Self-Assessment Framework

### Case for Testing

This research then aims to adopt a case study to test whether the self-assessment framework proposed in the current study has an excellent capability to be applied in practice. The demonstration process of the test case can further provide readers with a clear self-assessment guide. To ensure the appropriateness and sufficiency of the case study to gain insight into the phenomenon studied, the design of the case study follows the suggestions by Yin (2003) and Siggelkow (2007). First of all, to achieve structural validity, specific concepts and operational measures need to be determined, so that, the reference model of this study is based on SCOR and modified. Second, collect multiple sources of evidence to ensure the construct validity (Yin, 2003, p34). Finally, regarding the sufficiency of a case study, a single case study can be used to determine whether the theoretical propositions are correct, or whether certain alternative explanations may be more relevant (Yin, 2003, p40), in addition, from an explanatory point of view, researchers can obtain sufficient materials from a selected case for future research (Miles & Huberman, 1994).

The company featured as a case in this research (hereinafter referred to as “Company A”) was established in 1989 and has more than 20 years of experience in manufacturing engine components. Located in central Taiwan, its products are mainly for electric machine tools for woodworking machinery. Its capital amount is USD12 million dollars, and the largest annual sales are USD60 million dollars. It has 180 employees, with an average working duration of around 4 years, and most of them are college graduates. Company A also invests huge resources in product research and development. Its R&D division comprises 16 employees. Clients for Company A’s machine tools include world-renowned major machine tool factories. This case study of the company focuses on collecting internal business materials and interviewing senior management. An evaluation was conducted using the assessment questionnaire.

### Self-Assessment Analysis

This research applied the self-assessment framework to assess company A’s actual operations. First, company A employees filled in the question items as indicated in the framework. Then, the score for company A 4 years ago and the current score were calculated separately, as the basis for further comparative analysis. The score for each question item in the self-assessment framework is between 0 and 4, and the criteria are as follows: the score for a specific question item is 0 if checkbox #0 is ticked, 0.25 if checkbox #1 is ticked, 0.5 if checkbox #2 is ticked, and so on. Each score is then multiplied by the weight for that specific item. The weight is the priority vector value multiplied by 100. The priority vector values for each item are presented in Appendix 2. For example, for the priority vector value of 0.02746 for item C11 (The degree of rigorous mechanisms to select and assess suppliers) in the supplier dimension, the weighted value is 2.746. The overall score of the self-assessment is the sum of the quantified items.

The result indicates that from 4 years ago until now, scores for company A are increased for 29 items, lower for 1 item (The degree of capabilities for information integration, sharing, and communication (C76)), and unchanged for 3 items. Changes in the supply chain of company A are reviewed below from the perspective of the overall score for these eight dimensions.

For the supplier dimension, the score improved from 3 to 9. Company A mainly relies on the accumulation of experiences in its appropriate assessment of supplier selection. In the past, it was

unable to control the suppliers' supply capability, credit status, product quality, or equipment conditions because of its lack of experience in interacting with suppliers. It even suffered from deterioration of product quality for some products because of inappropriate supply. This caused company A to bear the cost of losses. Previously, company A carefully selected 5–6 upstream manufacturers as regular suppliers. Currently, orders are placed with only two of these suppliers, and company A offers consulting services on suppliers' product quality. Since the orders were aggregated to fewer suppliers and the orders increased, the company's ability to negotiate the price with the suppliers has been enhanced.

In the purchase dimension, the score for company A increased from 8 to 14. Company A purchases raw materials (such as copper and aluminum) every half year. Annual purchases will stabilize the influence of fluctuations in raw material costs if prices for raw materials can be predicted precisely. However, in the fields of raw materials and inventory, company A does not have a comprehensive control mechanism to train its purchasing staff in real-time material purchasing and inventory reduction. Company A needs to improve on this issue.

In the manufacturing dimension, the score for company A increased from 8 to 12. Company A is dedicated to quality management that meets international standards. It passed ISO 9002 and 9001 certifications in 1997 and 2002, respectively. In recent years, company A also invested a large number of funds to improve capability in product design and innovation of R&D. In similar industries, professional knowledge has to be utilized to develop high-value products to achieve market segmentation and a competitive edge.

In the shipping dimension, the score is unchanged at 3; there are no obvious changes between the past and now. Most of company A's products are sent by ocean shipment and the company is only responsible for the delivery of its products to ports.

In the market dimension, the scores for company A increased from 7 to 12. It has gradually undertaken a lot of work on customer relationship management.

In the planning dimension, the score has increased from 9 to 16. Company A has benefited from adopting ERP and e-FLOW systems to improve its organization process. However, due to the lack of a sound inventory mechanism, there has been no significant improvement in inventory management capabilities.

In the information technology dimension, the score has increased from 11 to 15. Although there has been an improvement in overall performance for the information technology dimension, factor C76 (The degree of capabilities of information integration, sharing, and communication)" is decreased. One possible reason is that company A's capacity, production manpower, equipment, and production have increased in its factory, but the information system requires improvement.

In the organizational integration dimension, the score has increased from 10 to 15. There are unofficial collaboration relationships between company A and some suppliers. After the long-term collaboration, company A has become a major client for these suppliers.

According to the self-assessment forms based on company A's actual situation and calculation of the weights of the eight major dimensions, we found that the score for company A was 45.20275 four years ago, and the current score has improved to 72.393 points. This indicates an obvious growth in company A's supply chain operation. It verifies that the results estimated by the self-assessment framework constructed in this study are valid and confirms that the GSCOM developed in this study is indeed feasible and effective.

## Conclusion and Implications

There is a significant gap between theoretically important supply chain management tools and ideas and the reality of organizations' operations. The current study described herein fills this gap with a tried and tested methodology to diagnose a global supply chain performance. In the preliminary phase of developing the self-assessment methodology, the current study collected a comprehensive list of impact factors from relevant studies and establish a hierarchy for the current complex research

issue. Forty-four possible critical success factors in the GSCOM are summarized from the literature and used for developing a prototype GSCOM. These factors are categorized into eight dimensions.

In the methodological adjustment phase, the current study utilized an expert survey for enhancing content effectiveness of the model, and use an AHP survey to evaluate the importance of the various impact factors and the dimensions. Specifically, a series of expert surveys were conducted to refine the 44 factors into 33. An AHP survey was later used to generate the weights for those factors to transform the GSCOM into a self-assessment framework.

Our exciting discoveries, the newly added 4 dimensions of GSCOM are ranked in order of 1 (market), 3 (information technology), 4 (organizational integration), and 6 (supplier), while those dimensions come from the SCOR model are ranked as 2 (planning), 5 (manufacturing), 7 (purchasing), and 8 shipping. This shows that traditional supply chain management mainly focuses on the primary activities in the organization's value chain (Porter, 1985). In contrast, the concept of global supply management tends to be broader and the dimensions are more complete. Especially in the coordination and cooperation between the market, the organization itself and suppliers, and the use of information technology as a communication tool.

In the final phase, this study developed a self-assessment framework to examine the effectiveness of the global supply chain. Besides, it was applied to a case study of company A to see if it was able to monitor the company's overall operational performance in the last few years and reveal in what areas it performed better than others.

According to the self-assessment forms based on company A's actual situation and calculation of the weights of the eight major dimensions, we found that the score for company A was 45.20275 four years ago, and the current score has improved to 72.393 points. This indicates an obvious growth in company A's supply chain operation. It verifies that the results estimated by the self-assessment framework constructed in this study are valid and confirms that the GSCOM developed in this study is indeed feasible and effective.

On the whole, the framework presented in this paper can be viewed as a diagnostic tool that allows companies to assess the state of their supply chain management.

## **Theoretical Implications**

SCOR, which was proposed by a consulting company many years ago and is the most famous reference model in supply chain management, does not always reveal the unique attributes of SMEs and effectively reflects the global division of manufacturing. Our study re-establishes the theoretical foundation of the SCOR model through an extensive literature review and focuses on the characteristics of SMEs against the background of globalization, which increases the importance of IT dimensions and organizational integration, and adds more comprehensive factor definitions in the marketing dimension. As a result, this study provides theoretical implications from the following three perspectives.

In terms of the first source of theoretical implications, this study employed the supply chain operation reference model to identify the significant elements in this academically underexplored, which is also a highly practical phenomenon around the global supply chain operations (Copacino, 2019; Taticchi et al., 2015). As Corley and Gioia (2011) point out, focusing on relevant practical issues not only enhances the practical utility of research but also serves as a good starting point for theoretical development and theoretical contributions. In addition, the existing literature on supply chain audit and diagnostics methodologies provide only scattered exploratory studies (Childerhouse & Towill, 2011; Gadiesh & Gilbert, 1998). It only focuses on activities that increase profits and do not provide a comprehensive view of the entire supply chain up/middle/downstream. Due to the lack of a theoretical foundation, the current study has initiated a new discussion on the framework of self-diagnosis of global supply chain operations. Thus, we can make theoretical contributions based on the apocalyptic insights in the field of supply chain management.

Regarding the second theoretical implication, we have presented a global supply chain operations reference framework that contains two novel, unexplored dimensions – information technology and organizational integration. We also provided exhaustive instruments for each dimension. As Whetten (1989) pointed out, theoretical insights come from reorganizing our research model to show how adding new variables can significantly change our understanding of phenomena. Specifically, 44 factors were selected based on a systematic literature review, and exhaustive instruments for each factor were proposed. With the measurement based on the theoretical and meaningful framework, we can utilize it in the practical world and make a real contribution to industries. Such efforts can also allow academic researchers to systematically advance the conceptual framework of supply chain operations in the consulting industry.

Finally, this study, to our knowledge, is among the first to examine the self-assessment measurements of global supply chain operations through a three-stage research design. By carefully applying the multi-phase research methodologies (Venkatesh, Brown, & Sullivan, 2016), we demonstrate how following the sequential mixed method approach - a systematic literature review, two quantitative AHP surveys, integrated with a case analysis- can help draw in-depth and meaningful findings and inferences. Specifically, we corroborate twelve experts from three different categories to verify and simplify self-assessment measurements. This ensures the triangulation in the current study, and, thus filling the gaps in the research methodologies and supply chain operation literature. The results will enable machine tool industries to understand the key indicators in the global supply chain operations and better manage them through technical and managerial improvements.

## Practical Implications

The results show that the self-assessment framework can help machine tool SMEs to monitor the performance of their global supply chains and identify areas for improvement to increase their competitiveness. Besides, this research also offers several practical implications.

Firstly, the self-assessment framework can quickly complete the evaluation and shorten the time distance between the two evaluations to conduct regular periodic evaluations as a response to rapid changes in the environment or competition. In particular, the self-assessment process of this measurement is simple and effective and can provide an effective approach for self-assessment by machine tool small and medium-sized enterprises. Enterprises can fill in the enterprise self-evaluation scale by senior managers to compare the self-evaluation results obtained in the past and the present, strengthen and improve all aspects of the model and its key factors, enhance integration and integration capabilities, and enhance its integration and communication with all supply chain member's ability, and increase the operational flexibility of SMEs to respond to changes in the industry environment.

Secondly, SMEs could affordably complete the assessment. By using this approach, companies can identify and implement activities to improve adherence to the GSCOM and realize global SCM benefits. The global supply chain operation model of small and medium-sized machine tool companies established by this research includes eight dimensions (suppliers, procurement, manufacturing, delivery, marketing, planning, information technology, and organization) and 33 key influencing factors. The supply chain operation of the machine tool industry can be simultaneously evaluated as a whole to improve the performance of the supply chain operation. This serves an efficient tool for supply chain performance measurement.

Thirdly, it can not only be used to discover the strengths and weaknesses of a company but also be used as a priority for resource allocation and management. If manufacturers in the machine tool industry want to survive and grow, they must effectively integrate with third-party manufacturers. For small and medium-sized enterprises with insufficient resources, the success or failure of the supply chain operation model plays a critical role in the relationship with the operation of the entire enterprise. The global supply chain operation evaluation model established in the current study can use the company's internal data and senior management's scale evaluation to more objectively examine

the company's competitive advantages and disadvantages. It is helpful to formulate a competitive business strategy and urgently utilize the limited resources of the company.

Finally, through a clear score presentation, and a specific reference model for senior management. It can be used as an objective basis for future management development or improvement. As small and medium-sized enterprises tend to have a highly centralized structure, most senior executives are decision-makers.

Using this global supply chain operation measurement tool, business owners or high-level managers can easily self-evaluate the operational performance of their supply chain and continuously revise the business model, enhance the core capabilities of their industry, and enhance the competitive advantages of the company's internationalization development.

### **Limitations and Future Research**

This study provides several suggestions for future research. First, the assessment framework can be further utilized for developing benchmarks for the whole industry. After assessing the global supply chain practices of companies in the machine tool industry, one company can understand more about the performances of its competitors in the industry, the areas in which others do better, and where there is room for improvement. Secondly, it is recommended that the assessment framework be revised for different industries. This research has developed quantified scale items for the assessment of global supply chains in the machine tool industry. However, industries differ in their industrial characteristics, which may affect the assessment nature of the framework. For example, a high-tech industry may emphasize the information technology dimension. Future research could extend or modify the proposed framework to fit other industries. Thirdly, the assessment framework could be revised to be used in large companies. This research focuses on SMEs, which possess characteristics different from those of large competitors. Because of their different characteristics, the assessment items developed for this study may not be directly applicable to large companies. For instance, large businesses may place more emphasis on the information technology dimension because of relatively greater available funds. Future researchers are encouraged to expand the assessment items for large enterprises.

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## REFERENCES

- Bi, R., Davidson, R., Kam, B., & Smyrniotou, K. (2013). Developing organizational agility through IT and supply chain capability. *Journal of Global Information Management*, 21(4), 38–55.
- Boehme, T., Ma, Y., Childerhouse, P., Corner, J., Seuring, S., Basnet, C., & Deakins, E. (2007). *The application of the Quick Scan Audit Methodology in SME's*. Paper presented at the Small Enterprise Conference.
- Bradley, F., Meyer, R., & Gao, Y. (2006). Use of supplier-customer relationships by SMEs to enter foreign markets. *Industrial Marketing Management*, 35(6), 652–665.
- Bradley, J. (2008). Management based critical success factors in the implementation of Enterprise Resource Planning systems. *International Journal of Accounting Information Systems*, 9(3), 175–200.
- Çelebi, D., & Bayraktar, D. (2008). An integrated neural network and data envelopment analysis for supplier evaluation under incomplete information. *Expert Systems with Applications*, 35(4), 1698–1710.
- Chang, W., Park, J. E., & Chaui, S. (2010). How does CRM technology transform into organizational performance? A mediating role of marketing capability. *Journal of Business Research*, 63(8), 849–855.
- Chen, J.-L. (2018). The Cases Study of “One Belt and One Road” and “Made in China 2025” Impact on the Development of Taiwan’s Machine Tool Industry. *International Business Research*, 11(2).
- Chen, L.-C. (2011). The governance and evolution of local production networks in a cluster: The case of Taiwan’s machine tool industry. *GeoJournal*, 76(6), 605–622.
- Chengalur-Smith, I., Duchessi, P., & Gil-Garcia, J. R. (2012). Information sharing and business systems leveraging in supply chains: An empirical investigation of one web-based application. *Information & Management*, 49(1), 58–67.
- Childerhouse, P. (1999). *A quick scan method for supply chain diagnostics*. Paper presented at the Proceedings of the Fourth International Symposium on Logistics, Florence, Italy.
- Childerhouse, P., & Towill, D. R. (2011). Effective supply chain research via the quick scan audit methodology. *Supply Chain Management*, 16(1), 5–10.
- Chopra, S., & Meindl, P. (2001). *Supply Chain Management: Strategy, Planning, and Operation*. Prentice Hall.
- Chou, D. C., Tan, X., & Yen, D. C. (2004). Web technology and supply chain management. *Information Management & Computer Security*, 12(4), 338–349.
- Chow, W. S. (2004). An exploratory study of the success factors for extranet adoption in e-supply chain. *Journal of Global Information Management*, 12(1), 60–67.
- Copacino, W. C. (2019). *Supply chain management: The basics and beyond*. Routledge.
- Corley, K. G., & Gioia, D. A. (2011). Building theory about theory building: What constitutes a theoretical contribution? *Academy of Management Review*, 36(1), 12–32.
- Dawes, P. L., Lee, D. Y., & Midgley, D. (2007). Organizational learning in high-technology purchase situations: The antecedents and consequences of the participation of external IT consultants. *Industrial Marketing Management*, 36(3), 285–299.
- Dewulf, J., Mancini, L., Blengini, G. A., Sala, S., Latunussa, C., & Pennington, D. (2015). Toward an overall analytical framework for the integrated sustainability assessment of the production and supply of raw materials and primary energy carriers. *Journal of Industrial Ecology*, 19(6), 963–977.
- Dhar, S., & Balakrishnan, B. (2006). Risks, benefits, and challenges in global IT outsourcing: Perspectives and practices. *Journal of Global Information Management*, 14(3), 59–89.
- Ding, S., & Kaminsky, P. M. (2019). Centralized and Decentralized Warehouse Logistics Collaboration. *Manufacturing & Service Operations Management*.
- Dong, Q., & Cooper, O. (2016). An orders-of-magnitude AHP supply chain risk assessment framework. *International Journal of Production Economics*, 182, 144–156.

- Dornfeld, D. A. (2014). Moving towards green and sustainable manufacturing. *International Journal of Precision Engineering and Manufacturing-Green Technology*, 1(1), 63–66.
- Elimam, A. A., & Dodin, B. (2013). Project scheduling in optimizing integrated supply chain operations. *European Journal of Operational Research*, 224(3), 530–541.
- Ellram, L. M., Tate, W. L., & Feitzinger, E. G. (2013). Factor-market rivalry and competition for supply chain resources. *The Journal of Supply Chain Management*, 49(1), 29–46.
- Fallahpour, A., Olugu, E. U., Musa, S. N., Wong, K. Y., & Noori, S. (2017). A decision support model for sustainable supplier selection in sustainable supply chain management. *Computers & Industrial Engineering*, 105, 391–410.
- Fayezi, S., Zutshi, A., & O'Loughlin, A. (2017). Understanding and development of supply chain agility and flexibility: A structured literature review. *International Journal of Management Reviews*, 19(4), 379–407.
- Fragnière, E., Gondzio, J., & Yang, X. (2010). Operations risk management by optimally planning the qualified workforce capacity. *European Journal of Operational Research*, 202(2), 518–527.
- Freund, C., Ferrantino, M., Maliszewska, M., & Ruta, M. (2018). Impacts on global trade and income of current trade disputes. *Macroeconomics, Trade Investment (MTI) Practice Notes*, 2.
- Fynes, B., Coughlan, P., von Haartman, R., & Bengtsson, L. (2015). The impact of global purchasing and supplier integration on product innovation. *International Journal of Operations & Production Management*.
- Gadiesh, O., & Gilbert, J. L. (1998). How to map your industry's profit pool. *Harvard Business Review*, 76(3), 149–152, 154, 156 passim.
- Gattorna, J. (2017). Supply chain management tools Minimizing the risks: maximizing the benefits. In *Strategic Supply Chain Alignment* (pp. 523–534). Routledge.
- Ghaderi, S. F., Azadeh, A., Nokhandan, B. P., & Fathi, E. (2012). Behavioral simulation and optimization of generation companies in electricity markets by fuzzy cognitive map. *Expert Systems with Applications*, 39(5), 4635–4646.
- Globerman, S., & Vining, A. R. (2017). The outsourcing decision: A strategic framework. In *Global outsourcing strategies* (pp. 27–40). Routledge.
- Gosain, S., Malhotra, A., & El Sawy, O. A. (2004). Coordinating for flexibility in e-business supply chains. *Journal of Management Information Systems*, 21(3), 7–45.
- Grover, V., & Saeed, K. A. (2007). The impact of product, market, and relationship characteristics on interorganizational system integration in manufacturer-supplier dyads. *Journal of Management Information Systems*, 23(4), 185–216.
- Gunasekaran, A., & Ngai, E. W. (2004). Information systems in supply chain integration and management. *European Journal of Operational Research*, 159(2), 269–295.
- Huan, S. H., Sheoran, S. K., & Wang, G. (2004a). A review and analysis of supply chain operations reference (SCOR) model. *Supply Chain Management*, 9(1), 23–29.
- Huan, S. H., Sheoran, S. K., & Wang, G. (2004b). A review and analysis of supply chain operations reference (SCOR) model. *Supply Chain Management*.
- Hudnurkar, M., & Rathod, U. (2017). Collaborative practices with suppliers in Indian manufacturing multinationals. *Journal of Global Operations and Strategic Sourcing*.
- Hung, S.-Y., Chang, S.-I., Hung, H.-M., Yen, D. C., & Chou, B.-F. (2016). Key success factors of vendor-managed inventory implementation in Taiwan's manufacturing industry. *Journal of Global Information Management*, 24(1), 37–60.
- Inman, R. R., & Blumenfeld, D. E. (2014). Product complexity and supply chain design. *International Journal of Production Research*, 52(7), 1956–1969.
- Jain, V., Kumar, S., Soni, U., & Chandra, C. (2017). Supply chain resilience: Model development and empirical analysis. *International Journal of Production Research*, 55(22), 6779–6800.

- Jazairy, A., Lenhardt, J., & von Haartman, R. (2017). Improving logistics performance in cross-border 3PL relationships. *International Journal of Logistics Research and Applications*, 20(5), 491–513.
- Kannan, V. R., & Tan, K. C. (2002). Supplier selection and assessment: Their impact on business performance. *The Journal of Supply Chain Management*, 38(3), 11–21.
- Kaufmann, A., & Tödtling, F. (2002). How effective is innovation support for SMEs? An analysis of the region of Upper Austria. *Technovation*, 22(3), 147–159.
- Kim, M.-h. (2019). A real driver of US–China trade conflict: The Sino–US competition for global hegemony and its implications for the future. *International Trade, Politics and Development*, 3(1), 30–40.
- Klaas-Wissing, T., & Albers, S. (2010). Cooperative versus corporate governance of LTL networks. *International Journal of Logistics: Research and Applications*, 13(6), 493–506.
- Kocaoğlu, B., Gülsün, B., & Tanyaş, M. (2013). A SCOR based approach for measuring a benchmarkable supply chain performance. *Journal of Intelligent Manufacturing*, 24(1), 113–132.
- Kottala, S. Y., & Herbert, K. (2019). An empirical investigation of supply chain operations reference model practices and supply chain performance. *International Journal of Productivity and Performance Management*.
- L, D. R. (2005). *Internationalising the quick scan audit methodology*. Paper presented at the 18th International Conference of Production Research, Salerno.
- Lancioni, R., Schau, H. J., & Smith, M. F. (2003). Internet impacts on supply chain management. *Industrial Marketing Management*, 32(3), 173–175.
- Lawshe, C. H. (1975). A quantitative approach to content validity 1. *Personnel Psychology*, 28(4), 563–575.
- Lee, C., Lee, Y. H., Peng, Y., & Cho, H. (2011). A supplier discovery framework for effective and efficient configuration of a supply chain. *International Journal of Industrial Engineering*, 18(3), 109–119.
- Li, L., Su, Q., & Chen, X. (2011). Ensuring supply chain quality performance through applying the SCOR model. *International Journal of Production Research*, 49(1), 33–57.
- Lima-Junior, F. R., & Carpinetti, L. C. R. (2019). An adaptive network-based fuzzy inference system to supply chain performance evaluation based on SCOR® metrics. *Computers & Industrial Engineering*, 106191.
- Lin, Y., Liang, B., & Zhu, X. (2018). The effect of inventory performance on product quality. *International Journal of Quality & Reliability Management*.
- Liu, H., Wei, S., Ke, W., Wei, K. K., & Hua, Z. (2016). The configuration between supply chain integration and information technology competency: A resource orchestration perspective. *Journal of Operations Management*, 44, 13–29.
- Liu, J., Zhang, S., & Hu, J. (2005). A case study of an inter-enterprise workflow-supported supply chain management system. *Information & Management*, 42(3), 441–454.
- Luo, X., Wu, C., Rosenberg, D., & Barnes, D. (2009). Supplier selection in agile supply chains: An information-processing model and an illustration. *Journal of Purchasing and Supply Management*, 15(4), 249–262.
- Miles, M. B., & Huberman, A. M. (1994). *Qualitative Data Analysis: An Expanded Sourcebook*. Sage publications.
- Motade, M., Toloie-Eshlaghy, A., & Halvachi-Zadeh, D. (2011). Assessment of supply chain agility in the automotive industry of Tehran. *European Journal of Scientific Research*, 61(2), 210–229.
- Movahedi, B., Miri-Lavassani, K., & Kumar, U. (2016). Operational excellence through business process orientation: An intra-and inter-organizational analysis. *The TQM Journal*, 28(3), 467–495.
- Nair, A. (2005). Linking manufacturing postponement, centralized distribution and value chain flexibility with performance. *International Journal of Production Research*, 43(3), 447–463.
- Ohshima, M. (2003). Control and design problems in material processing—How can process systems engineers contribute to material processing? *Journal of Process Control*, 13(7), 599–605.

- Ou, J.-S., Chang, S.-I., & Lee, C.-H. (2006). *A Study of Global Supply Chain Operation Mode of Small and Medium Enterprises: A Midterm Report*. Small and Medium Enterprise Administration, Ministry of Economic Affairs.
- Palma-Mendoza, J. A. (2014). Analytical hierarchy process and SCOR model to support supply chain re-design. *International Journal of Information Management*, 34(5), 634–638.
- Paul, W. T., Semeijn, J., & Ernstson, S. (2010). Supplier satisfaction and commitment: The role of influence strategies and supplier development. *Journal of Purchasing and Supply Management*, 16(1), 17–26.
- Paulraj, A., Chen, I. J., & Flynn, J. (2006). Levels of strategic purchasing: Impact on supply integration and performance. *Journal of Purchasing and Supply Management*, 12(3), 107–122.
- Poluha, R. G. (2016). Introduction: The real competition will be between supply chains in the future. In *The quintessence of supply chain management* (pp. 1-8). Springer.
- Porter, M. E. (1985). *The Competitive Advantage: Creating and Sustaining Superior Performance*. Free Press.
- Purchase, S., Goh, T., & Dooley, K. (2009). Supplier perceived value: Differences between business-to-business and business-to-government relationships. *Journal of Purchasing and Supply Management*, 15(1), 3–11.
- Quayle, M. (2003). A study of supply chain management practice in UK industrial SMEs. *Supply Chain Management*, 8(1), 79–86.
- Rodríguez, M. A., & Vecchiotti, A. (2009). Integrating Purchase Contract Decisions with Inventory Management Optimization in the Supply Chain. *Computer-Aided Chemical Engineering*, 27, 315–320.
- Rungtusanatham, M. (2001). Beyond improved quality: The motivational effects of statistical process control. *Journal of Operations Management*, 19(6), 653–673.
- Rushton, A., Croucher, P., & Baker, P. (2014). *The handbook of logistics and distribution management: Understanding the supply chain*. Kogan Page Publishers.
- Saaty, T. (1980). *The analytic hierarchy processes: Planning, priority setting resource*. Mc Graw.
- Schadel, J., Lockström, M., Moser, R., & Harrison, N. (2016). Readiness for Supply Chain Collaboration and Supplier Integration—Findings from the Chinese Automotive Industry. In *Developments in Logistics and Supply Chain Management* (pp. 125–137). Springer.
- Scott, C., Lundgren, H., & Thompson, P. (2011). Guide to Outsourcing in Supply Chain Management. In *Guide to Supply Chain Management* (pp. 169–182). Springer.
- Sellitto, M. A., Pereira, G. M., Borchardt, M., da Silva, R. I., & Viegas, C. V. (2015). A SCOR-based model for supply chain performance measurement: Application in the footwear industry. *International Journal of Production Research*, 53(16), 4917–4926.
- Seth, M., Goyal, D., & Kiran, R. (2017). Diminution of impediments in implementation of supply chain management information system for enhancing its effectiveness in Indian automobile industry. *Journal of Global Information Management*, 25(3), 1–20.
- Sheu, J.-B. (2008). A hybrid neuro-fuzzy analytical approach to mode choice of global logistics management. *European Journal of Operational Research*, 189(3), 971–986.
- Siggelkow, N. (2007). Persuasion with case studies. *Academy of Management Journal*, 50(1), 20–24.
- Simon, A. T., Serio, L. C. D., Pires, S. R. I., & Martins, G. S. (2015). Evaluating supply chain management: A methodology based on a theoretical model. *Revista de Administração Contemporânea*, 19(1), 26–44.
- Song, H., Yu, K., Ganguly, A., & Turson, R. (2016). Supply chain network, information sharing and SME credit quality. *Industrial Management & Data Systems*, 116(4), 740–758.
- Srinivasan, R., & Swink, M. (2018). An investigation of visibility and flexibility as complements to supply chain analytics: An organizational information processing theory perspective. *Production and Operations Management*, 27(10), 1849–1867.
- Stephens, S. (1999). Supply Chain Council (Hrsg.): Supply Chain Council & Supply Chain Operations Reference (SCOR) Model Overview. Academic Press.

- Tan, E., Smith, G., & Saad, M. (2006). Managing the global supply chain: A SME perspective. *Production Planning and Control*, 17(3), 238–246.
- Taticchi, P., Garengo, P., Nudurupati, S. S., Tonelli, F., & Pasqualino, R. (2015). A review of decision-support tools and performance measurement and sustainable supply chain management. *International Journal of Production Research*, 53(21), 6473–6494.
- Tiwari, A. K., Tiwari, A., & Samuel, C. (2015). Supply chain flexibility: A comprehensive review. *Management Research Review*, 38(7), 767–792.
- Towill, D. R. (1999). ‘Management theory’: Is it of any practical use? or how does a fad become a paradigm? *Engineering Management Journal*, 9(3), 111–121.
- Tracey, M., Lim, J.-S., & Vonderembse, M. A. (2005). The impact of supply-chain management capabilities on business performance. *Supply Chain Management*, 10(3), 179–191.
- Tseng, P.-H., & Liao, C.-H. (2015). Supply chain integration, information technology, market orientation and firm performance in container shipping firms. *International Journal of Logistics Management*, 26(1), 82–106.
- Tsiakis, P., & Papageorgiou, L. G. (2008). Optimal production allocation and distribution supply chain networks. *International Journal of Production Economics*, 111(2), 468–483.
- Uniyal, S., Mangla, S. K., Sarma, P. R., Tseng, M.-L., & Patil, P. (2021). ICT as “Knowledge management” for assessing sustainable consumption and production in supply chains. *Journal of Global Information Management*, 29(1), 164–198.
- Venkatesh, V., Brown, S. A., & Sullivan, Y. W. (2016). Guidelines for conducting mixed-methods research: An extension and illustration. *Journal of the Association for Information Systems*, 17(7), 2.
- Wang, T.-K., Zhang, Q., Chong, H.-Y., & Wang, X. (2017). Integrated supplier selection framework in a resilient construction supply chain: An approach via analytic hierarchy process (AHP) and grey relational analysis (GRA). *Sustainability*, 9(2), 289.
- Whetten, D. A. (1989). What constitutes a theoretical contribution? *Academy of Management Review*, 14(4), 490–495.
- Williamson, O. E. (2008). Outsourcing: Transaction cost economics and supply chain management. *The Journal of Supply Chain Management*, 44(2), 5–16.
- Wojczewski, T. (2019). Trump, Populism, and American Foreign Policy. *Foreign Policy Analysis*. Advance online publication. doi:10.1093/fpa/orz021
- Wong, C. W., Lai, K.-h., & Bernroider, E. W. (2015). The performance of contingencies of supply chain information integration: The roles of product and market complexity. *International Journal of Production Economics*, 165, 1–11.
- Xu, X. (2017). Machine Tool 4.0 for the new era of manufacturing. *International Journal of Advanced Manufacturing Technology*, 92(5-8), 1893–1900.
- Yang, J., Lai, K. H., Wang, J., Rauniar, R., & Xie, H. (2015). Strategic alliance formation and the effects on the performance of manufacturing enterprises from supply chain perspective. *International Journal of Production Research*, 53(13), 3856–3870.
- Yeniyyurt, S., Wu, F., Kim, D., & Cavusgil, S. T. (2019). Information technology resources, innovativeness, and supply chain capabilities as drivers of business performance: A retrospective and future research directions. *Industrial Marketing Management*, 79, 46–52.
- Yin, R. K. (2003). *Case Study Research: Design and Methods* (Vol. 5). Sage publications.
- Zheng, P., Sang, Z., Zhong, R. Y., Liu, Y., Liu, C., Mubarak, K., & Xu, X. et al. (2018). Smart manufacturing systems for Industry 4.0: Conceptual framework, scenarios, and future perspectives. *Frontiers of Mechanical Engineering*, 13(2), 137–150.
- Zhou, H., Benton, W. Jr, Schilling, D. A., & Milligan, G. W. (2011). Supply chain integration and the SCOR model. *Journal of Business Logistics*, 32(4), 332–344.

## APPENDIX A – ADDITIONAL TABLES

Table 5. Globalized supply chain operation model for machine tool small and medium enterprises self-assessment framework

Dimension	Item	Measurement Items	4 Years before					Now				
			4	3	2	1	0	4	3	2	1	0
<b>S1 Supplier</b>	C11	The degree of rigorous mechanisms to select and assess suppliers										
	C12	The degree of close collaboration with suppliers										
	C13	The degree of integration and strategic alliance with supplier										
<b>S2 Purchasing</b>	C21	The degree of reaching of economies of scale in purchasing										
	C22	The degree of transparency in purchasing price										
	C23	The degree of centralized purchasing on key raw materials										
	C24	The degree of drafting of purchasing policy										
	C25	The ability to control over material and inventory										
<b>S3 Manufacturing</b>	C31	The ability to control on key raw material										
	C32	The efficiency of hiring technical manpower										
	C33	The degree of conforming to international standard quality management process										
	C34	The ability to design and improvement on product development										
<b>S4 Shipping</b>	C41	The degree of establishment of effective shipping mode										
<b>S5 Market</b>	C51	The ability to collection of respective market information and analysis of market trend										
	C52	The ability to assessment and master over information on competitor's quality, price and service										
	C53	The degree of excellent marketing capability										
	C54	The degree of customer relationship management enhancement										
<b>S6 Planning</b>	C61	The degree of simplify process and lower costs for the company										
	C62	The ability to inventory management improvement										
	C63	The degree of operation process management improvement										
	C64	The degree of appropriate utilization and cultivation of human resources										
	C65	The degree of independent capability for strategic planning										

*continued on next page*

Table 5. Continued

Dimension	Item	Measurement Items	4 Years before					Now				
			4	3	2	1	0	4	3	2	1	0
<b>S7 Information Technology</b>	C71	The degree of basic internet application										
	C72	The degree of complete and rigorous design of information system software and hardware										
	C73	The degree of adopting the electronic system										
	C74	The degree of standardization over programming language and communication protocol										
	C75	The degree of integration and maintenance of the platform among businesses										
	C76	The degree of capabilities of information integration, sharing and communication										
<b>S8 Organizational integration</b>	C81	The degree of up/middle/downstream supply chain integration										
	C82	The degree of up/middle/downstream supply chain strategic alliance										
	C83	The degree of enhancement and speeded up on communication transparency										
	C84	The degree of enhancement of coordination and collaboration among supply chain members										
	C85	The degree of industrial cluster/network pattern										

(Data Source: This study)

## APPENDIX 2

Table 6. Overall indicators of the impact factor assessment criteria of priority vector-value comparison

Dimension	Items	priority vector-value	Importance Ranking
S5 Market	C54	0.06498	1
S4 Shipping	C41	0.05700	2
S5 Market	C53	0.05187	3
S3 Manufacturing	C34	0.04283	4
S8 Organizational Integration	C83	0.04263	5
S5 Market	C52	0.04009	6
S6 Planning	C62	0.03701	7
S8 Organizational Integration	C84	0.03683	8
S7 Information Technology	C76	0.03616	9
S6 Planning	C64	0.03448	10
S6 Planning	C63	0.03431	11
S5 Market	C51	0.03306	12
S3 Manufacturing	C31	0.03303	13
S7 Information Technology	C75	0.03296	14
S6 Planning	C61	0.03194	15
S1 Supplier	C12	0.03171	16
S6 Planning	C65	0.03110	17
S7 Information Technology	C72	0.02928	18
S1 Supplier	C11	0.02746	19
S3 Manufacturing	C32	0.02710	20
S1 Supplier	C13	0.02584	21
S7 Information Technology	C74	0.02512	22
S2 Purchasing	C25	0.02431	23
S7 Information Technology	C73	0.02400	24
S8 Organizational Integration	C81	0.02248	25
S8 Organizational Integration	C82	0.02233	26
S8 Organizational Integration	C85	0.02074	27
S3 Manufacturing	C33	0.01791	28
S2 Purchasing	C23	0.01504	29
S2 Purchasing	C24	0.01431	30
S7 Information Technology	C71	0.01248	31
S2 Purchasing	C21	0.01051	32
S2 Purchasing	C22	0.00876	33

(Data Source: This study)



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