Performance Measurement of Manufacturing Supply Chain

Wei Wei

A Thesis

In

The Department

of

Concordia Institute for Information Systems Engineering

Presented in Partial Fulfillment of the Requirements
for the Degree of Master of Applied Science of Quality Systems Engineering at
Concordia University
Montreal, Quebec, Canada

Feb 2014

CONCORDIA UNIVERSITY
School of Graduate Studies

This is to certify that the thesis prepared

By: Wei Wei

Entitled: Performance Measurement of Manufacturing Supply Chain
And submitted in partial fulfillment of the requirements for the degree of

Master of Applied Science (Quality Systems Engineering)

Complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

Signed by the final Examining Committee:

Dr. A. Ben Hamza	Chair
Dr. X. Huang	Examiner
Dr. C. Wang	Examiner
Dr. A. Schiffauerova	Supervisor

Approved by: Dr. R. Dssouli, Director
Concordia Institute for Information Systems Engineering
Dr. C. W. Trueman, Interim, Dean
Faculty of Engineering and Computer Science

Date: Jan 13, 2014

Abstract

Performance Measurement of Manufacturing Supply Chain

Wei Wei

In order to achieve a fully integrated manufacturing supply chain and to maximize its effectiveness and efficiency, the manufacturing supply chain needs to be assessed for its performance. My thesis has two main objectives: 1. To develop a new methodology for the performance measurement of manufacturing supply chain. 2. To evaluate manufacturing supply chain performance and carry out a comparative analysis of existing supply chains.

To accomplish the first objective a simple, generic and comprehensive tool for measuring the performance of supply chains was developed. The tool was validated by several interviews from various industries.

In order to achieve the second objective the proposed tool was used as a basis for a questionnaire, and a survey of the manufacturing supply chains across various countries and industries was conducted. The results show that even though performance measurement in the whole supply chain is considered as critical by many respondents, some supply chains have not implemented any performance measurement system. A four-factor index for the assessment of the supply chain performance was developed and used. The results suggest that the supply chains which use performance measurement systems are perceived as better performing than those which do not use any performance measurement systems. Also, the weighted performance scores for the national supply chains were higher than the scores for the international ones. Finally, supply chains with strategic alliance showed better performance than those which do not have strategic alliance.

Table of Contents

1. Introduction

In order to achieve a fully integrated supply chain (SC) and to maximize its effectiveness and efficiency, the SC needs to be assessed for its performance, i.e. the performance measures and metrics should be developed and deployed (Basnet, 2003; Beamon, 1998). This will not only help in improvement of performance of SC and in the in pursuit of SC excellence (Beamon, 1999), but also it will also facilitate a greater understanding of the SC and positively influence actors' behavior (Beamon, 2001). Nevertheless, it is widely acknowledged that only little attention in the literature has been given to the evaluation of SC performance measurement systems and metrics (e.g. Basnet, 2003; Beamon, 1998; Beamon, 1999; Bititci, 2005; Bourne, 2002). The existing research into SC performance measurement systems and metrics involves mainly their categorization (e.g. Benton, 2005; Bourne, 2000), the design of conceptual frameworks by which performance measurement systems can be developed for various types of systems (Beamon, 1998; Boyer, 2002), or the development and the implementation of performance measures for SC management (Beamon, 1998; Benton, 2005; Bititci, 2005; Brewer, 2000; Caprice, 1994).

Current SC performance measurement systems are reported to suffer from numerous deficiencies (Basnet, 2003; Beamon, 1998; Benton, 2005; Bourne, 2002; Caprice, 1995). One of the deficiencies which is most discussed in the literature is the lack of a systemic approach (Beamon, 1999; BS4778, 1987; Bourne, 2002) and a SC holistic context (Benton, 2005; Bourne, 2002). Shepherd and Gunter (1998) suggest addressing the lack of systemic approach to SC performance measurement by integrating performance measurement systems with modern manufacturing practices, such as Just in Time (JIT) or Total Quality Management (TQM). It has already been shown by Wood et al. (Chan, 2003) that the integration of these modern manufacturing practices can lead to statistically significant increases in performance. Flynn and Flynn (2002) proposed that the integration of quality goals with SC goals will create cumulative capabilities and, in the same vein, Kannan and Tan (2001) suggested that simultaneous commitment to both quality and SC improvement will have the greatest effect on performance.

However, comprehensive SC performance measurement systems and metrics could not be found in literature. This thesis proposes a novel methodology for the manufacturing SC performance

evaluation, which consists in the integration of the concepts of manufacturing SC management with balanced scorecard.

We can observe that in many research studies (e.g. Brewer, 2000; Besterfield-Sacre, 2003; Chen, 2007), the SC performance measurement systems are studied. Many different types of performance measurement systems are suggested, for example Balanced Scorecard (BSC), Total Quality Management (TQM), Supply Chain Operations Reference (SCOR) and so on. They are cited commonly in manufacturing SC performance measurement field. However, while I read through the research studies related to Balanced Scorecard, Total Quality Management or Supply Chain Operations Reference I could not find very detailed implementation information on how they are applied in industries. Based on the literature review which I have conducted I have found several research gaps, which I have addressed in this thesis. First, even though there are a few articles which mention the implementation in industry, they are discussing concerning it within an individual company's SC, not in the whole SC (e.g. Barbara, 2010; Milind, 2007). For example, in an electronic manufacturing services company whose main products are laptops, the company's SC involves its various suppliers (e.g. supplying battery, keyboard, and mechanical parts and so on). Its SCs are mainly these suppliers. However, in the whole SC concept, we can only regard this company as a manufacturer among the whole SC, including end-user, retailer, distributor, manufacturer and supplier. Also as we know, EMS company is focusing on manufacturing, assembling. It is easy to identify its role among the whole SC.

Second, there are some research studies which discuss the concept of BSC, e.g. the Balanced Scorecard framework including customer perspective, internal business perspective, financial perspective and innovation and learning perspective (Rajat, 2007; Brewer, 2000). There are also some works which mention attributes in detail for particular categories (e.g. Beamon, 1999; Rajat, 2007), but we cannot find a comprehensive system of attributes. Meanwhile, different attributes may produce various kinds of impacts on the manufacturing SC in a variety of levels. It is thus proposed in this thesis that every attribute in a performance measuring system should not be considered as having an equal impact on manufacturing SC performance. I tried to define different attribute's weights as representative to present the performance of whole manufacturing SC by applying objective statistical analysis.

Third, various research articles create different categories of performance measurement of manufacturing SC. for example, Beamon(1999) proposes three separate categories of performance measures including resource measures, output measures and flexibility measures. However, based on my working experience and several interviews with professionals from different industries, I created a more comprehensive categorization which is resource, customer-based, interaction, SC-based Interaction and flexibility.

Moreover, there is not any SC performance measuring system which could be applied to measure all types of manufacturing SCs. Here in the thesis I propose a more generic tool, which will be defined by 23 typical attributes which can apply to all types of manufacturing SCs. The following chapter will introduce the literature review in a good detail in order to present well the research gaps.

2. Literature review

2.1 Manufacturing supply chain management

As business evolves into the 21st century, supply chain management (SCM) is the predominant management focus driving many organizations. A recent study cited SCM as one of the three most important management practices which will decide about world class performance. Since its introduction in retailing, the SC concept has spread to other industries, including automotive, electronics, and chemicals. SCM is fast becoming critical for any company which intends to stabilize its position in the market (Brewer, 2000). This is the same situation for Canadian companies. Globalization of the market, growing competition and an increasing emphasis on customer satisfaction are regularly considered to be the catalysts in the growing interest in SCM (Gunasekaran, 2001; Webster, 2002). Effective SCM is considered as a key to building a sustainable competitive advantage via improved relationships within and among firms (Ellinger, 2000). SCs involve all activities related to the flow and transformation of goods from the raw material stage through to the end user (Handfield, 1999). Many benefits have been associated with SCM, for example reduced costs, increased market share and sales, and improved customer relations (Fergueson, 2000). Moreover, it has been suggested that measuring SC performance can

facilitate a greater understanding of the SC, positively influence actors' behaviour, and improve its overall performance (Chen, 2004). However, there is some evidence to suggest that this may be a dream rather than organizational reality. For example, according to Deloitte Consulting only 2% of North American manufacturers considered their SCs as world class, in spite of the fact that 91% of them viewed SCM as important, or critical, to organizational success (Thomas, 1999). Similarly, an international study of modern manufacturing practices reported only moderate perceived effectiveness of SCM among the examined companies (Clegg, 2002). In view of these modest levels of improvement and effectiveness, it could be expected that an increased interest in developing measurement systems and metrics for evaluating SC performance will appear.

A SC involves all the activities related to moving goods from the raw material stage through to the end-user. It includes many different companies, for example those engaged in processing raw materials, wholesaling and retailing, transportation, warehousing, information processing, and materials handling. Functions which are carried out through the SC include sourcing, procurement, production scheduling, manufacturing, order processing, inventory management, warehousing, and customer service. SC can be managed in either an integrated or disintegrated manner. Integrated SCM focuses on managing relationships, information, and material flow across organizational borders, and through the integration it is expected that the costs are cut and flow enhanced. Companies following the SCM approach usually attempt to achieve the integration of their logistics, procurement operations, and marketing functions with other SC members, so that materials, information, component parts, and finished product flow smoothly from the beginning until the end-user at lowest possible cost while providing the customers with high levels of service. SCM is based on partnership and cooperation of the involved companies, otherwise it would be difficult to achieve an integration of effort. SCM may require the companies to share sensitive and proprietary information about customers, actual demand, point-of-sale transactions, corporate strategic plans, and the like. It involves a great amount of planning and communication among the companies, and often involves teams of people that cut across functional and company boundaries to coordinate the movement of product to market. To say it differently, in order to achieve the real potential of SCM an integration not only among departments within the organization but also with external partners is required. Every company within the SC must break the functional hierarchy within its organization and encourage true

coordination and integration of marketing, production, procurement, sales, and logistics. Moreover, actions, systems, and processes among all the SC participants must be integrated and coordinated. This means that the integration within a company is a necessary, but not sufficient condition for achieving the full potential benefits of SCM. Integration must be achieved at the higher level as well, by which functions and processes can become truly coordinated across all the organizations in the SC (Bourne , 2000).

However, the implementation of SCM is not an easy task, and many obstacles are usually encountered. Some of these obstacles are shown in **Table 1**. As it was discussed, SCM involves sharing of proprietary information, strategy, planning, and goals and companies usually do not feel comfortable exposing such elements to other companies, because they are afraid of a loss of control (Benton, 2005).

Table 1 (Benton, 2005)

Barriers to effective supply chain management:

1. Failure to share information
2. Fear of loss of control
3. Lack of self awareness
4. Lack of partner awareness
5. Enormity of supply chain
6. Lack of supply chain satisfaction
7. Lack of customer understanding
8. Lack of understanding of supply chain
9. Myopic strategies
10. Deficiency of mutuality

2.2 Performance measurement of manufacturing supply chain

As was discussed above, manufacturing SC is a complicated system and the managing manufacturing SC is a difficult task. Now, let us discuss the performance measurement of manufacturing SC which is one of the most important aspects of manufacturing SCM.

Neely et al. (1995) define performance measurement as "the process of quantifying the effectiveness and efficiency of action. Effectiveness is the extent to which a customer's requirements are met and efficiency measures how economically a company's resources are utilised when providing a pre-specified level of customer satisfaction." Performance measurement systems are described as the overall set of metrics used to quantify both the efficiency and effectiveness of action .Many approaches to performance measurement have been discussed in the literature, for example the balanced scorecard (Kaplan, 1992); the performance measurement matrix (Keegan, 1989); performance measurement questionnaires (Dixon, 1990); criteria for measurement system design (Globerson, 1985); and computer aided manufacturing approaches. However, existing approaches are often criticised, where their main limitations are proposed to be the fact that they encourage short termism; they lack strategic focus (the measurement system is not aligned correctly with strategic goals, organization culture or reward systems); they encourage local optimisation by forcing managers to minimise the variances from standard, rather than seek to improve continually; and, they fail to provide adequate information on what competitors are doing through benchmarking (Shepherd, 2006). Neely et al. (1995) provide an overview of performance measurement, which has been widely cited in recent research into SC measurement systems and metrics (e.g. Beamon, 1999; Beamon, 2001; Gunasekaran, 2001; Gunasekaran, 2004). These papers, together with other similar studies, have suggested that the majority of the limitations cited by Neely et al. (1995) are greatly important in the case of performance measurement systems for SCs. Moreover, the need to develop new measurement systems and metrics which would remove these limitations has been suggested. The research in the area of performance measurement systems then focused on a number of important issues, for example the factors that affect the successful implementation of performance measurement systems (Bourne, 2000; Bourne, 2002); the forces which shape the evolution of performance measurement systems (Kennerley, 2002; Waggoner, 1999); the way of maintaining performance measurement systems which would allow them to be flexible and remain aligned with dynamic environments and changing strategies (Bourne, 2000; Kennerley, 2003).

The development of performance measurement systems is an important research area which involves creating the methods by which an organization can build its measurement system.

Important questions must be addressed here, as for example what should be measured, how multiple measures will be integrated into one coherent measurement system, the frequency of the measurements and the issues of re-evaluation. In general, it is difficult to develop a good measurement system for the SC or chains of interest (Beamon, 1999). Neely et al. (1995) makes an overview of various measurement frameworks which have been developed and of criteria for the measurement system design. However, it is argued that a generally applicable systematic approach to performance measurement has not been developed. There are many kinds of systems, where each of them requires different specific measurement system characteristics, which makes creating such a general approach very difficult. Some of the previous studies have attempted to develop various performance measure frameworks pertinent to different types of systems that share certain typical important characteristics (Beamon, 1999).

The limitations cited for the performance measurement systems for the SCs are similar to the limitations of measurement systems found in the more general management literature (Neely, 1995). These include:

- Lack of connection with strategy (Beamon, 1999; Chan, 2003; Gunasekaran, 2004)
- Focus on cost while neglecting non-cost indicators (Beamon, 1999; De Toni, 2001)
- Lack of a balanced approach (Beamon, 1999; Chan, 2003)
- Little focus on customers and competitors (Beamon, 1999)
- Focus on local optimization instead of SC optimization (Beamon, 1999)
- Lack of system thinking (Chan, 2003)

Researchers have responded to these limitations by proposing performance measurements systems which are systemic and balanced. One of the most recognized systems is the Supply Chain Operations Reference (SCOR) model, which was developed by the Supply Chain Council in 1997. It has been described as a 'systematic approach for identifying, evaluating and monitoring supply chain performance' (Stephens, 2001). The most critical factor for this model is a balanced approach. It is proposed that single indicators (e.g. cost or time) cannot be adopted to measure supply chain performance, instead, it is suggested to measure the SC performance at multiple levels.

Consequently, business processes, technology and metrics are all included in the model, which offers 5 groups of metrics; reliability, responsiveness, flexibility, cost and efficiency. There has been a criticism that the model does not provide a systematic method for prioritizing measures. However, recently some researchers have proposed to combine the method decision making tools such as Analytic Hierarchy Processing, or AHP (Huang, 2004; Li, 2005). Nevertheless, AHP is considered as the most appropriate technique for selecting measures by everybody. For example, even though Chan (2003) supports the of AHP, Chan and Qi (2003) argue that it is not very effective and propose to use fuzzy ratios instead.

Beamon (1996 proposed several characteristics which should be used in evaluation of the performance measurement systems. These characteristics are listed as follows: inclusiveness (measurement of all important aspects), universality (to enable comparisons under various operating conditions), measurability (data required are measurable), and consistency (measures are consistent with organization goals).

2.3 Implementation of performance measurement systems

Even though many research studied on the performance measurement systems could be found in the literature, much less attention has been given to the performance measurement systems implementation (Mee, 1998; Bourne, 1999; Hudson, 2001). The main reasons for success and failure have been categorized into 3 groups, which are contextual issues, processual issues and content issues (Bourne, 2002)

1. Contextual issues: (Bourne, 2002)

- The required information system needed to be highly developed (Bierbusse, 1997)
- The required time and expense were significant (Bierbusse, 1997; McCunn, 1998)
- There was lack of leadership and great resistance to change (Hacker, 1998; Meekings, 1995)

2. Processual issues: (Bourne, 2002)

- Vision and strategy were not practical and easy to translate into actions (Kaplan, 1996). There were difficulties in evaluating the relative importance of measures and the problems of identifying true "drivers" (Bierbusse, 1997; Schneiderman, 1999)
- Strategy was not directly connected to the allocation of resources (Kaplan, 1996; Meekings, 1995)
- Goals did not reflect the requirements of stakeholders (Schneiderman, 1999)
- The improvement methods which were used were not the best available (Schneiderman, 1999)
- Perfectionism has undermined success (McCunn, 1998; Schneiderman, 1999)

3. Content issues: (Bourne, 2002)

- Strategy was not connected to the goals at the level of departments, teams and individuals (Kaplan, 1996; Bierbusse, 1997; Schneiderman, 1999)
- Too many measures were used (Bierbusse, 1997)
- Metrics were not well defined (Schneiderman, 1999)
- The qualitative results were difficult to quantify (Bierbusse, 1997)

Categorization of the performance measures

Another problem is related to the method used to evaluate the performance. Only a few researchers have attempted to systematically gather measures for evaluating the performance of SCs. Moreover, the consensus over the most appropriate way to categorise them has not been reached in the literature. For example, Shepherd (2006) has recorded several types of groupings of the measures:

- Qualitative versus quantitative measures (Beamon, 1999; Chan, 2003)
- The subject of the measure: cost versus non-cost (Gunasekaran, 2001; De Toni, 2001); quality, cost, delivery or flexibility (Scho¨nsleben, 2004); cost, quality, resource utilization, flexibility, visibility, trust or innovativeness (Chan, 2003); resources, outputs or flexibility (Beamon, 1999); supply chain collaboration efficiency; coordination efficiency or configuration (Hieber, 2002); and, input, output or composite measures (Chan, 2003)
- The level of the measures: strategic, operational or tactical (Gunasekaran, 2001)

- The related process in the supply chain (e.g. Chan, 2003; Huang, 2004; Li, 2005; Lockamy, 2004; Stephens, 2001)

Another categorization has been proposed by Chan and Qi (2003) who divide the SC into six core processes (supplier, inbound logistics, manufacturing, outbound logistics, marketing and sales, end customers). For each of these core processes they the authors present input, output and composite measures. Similarly, the supporters of the supply chain operations reference (SCOR) model, (e.g. Huang, 2004; Li, 2005; Lockamy, 2004; Stephens, 2001) argue that SC performance must be measured at multiple levels. They assign five categories of metrics to level 1 of this model; reliability, responsiveness, flexibility, cost and efficiency indicators.

Financial aspect of SC performance measurement has been focus of many companies. However, it has been proposed by (Kaplan & Norton, 1996) that the evaluation methods which are based on financial measures are not suitable for newer generation of SCM applications. Many companies realized the potentials of SCM in their operations management, but they are often not able to develop effective performance measures and metrics. One of the reasons is that they lack a balanced approach and do not distinguish between metrics at strategic, tactical, and operational levels (Gunasekaran, 2001; Hudson, 2001). An effective SCM must consider the metrics which represent a balanced approach and which are classified at strategic, tactical, and operational levels, and which include both financial and non-financial measures (Rajat, 2007).

In summary, the need and importance of adopting a systemic and balanced approach while designing performance measurement systems for SCs have been generally recognized in the literature. However, a few gaps in the research related to the SC performance systems measurement have been identified. .

First, the performance measurement systems have not been integrated with human resource management (HRM) and modern manufacturing practices such as TQM, business process re-engineering, JIT, or new information technologies (Shepherd, 2006). This is important since as Wood et al. (2004) observe that the combination of these practices can lead to important increases in success. Moreover, even though certain metrics are highly supported by some of the manufacturing practices, they are not aligned with the strategic objectives. For example, JIT

encourages low inventory levels, but this can in fact contradict the strategic goal of increased SC flexibility. Second, existing measurement systems for evaluating the performance of SCs are not very dynamic; in fact they are rather static. Therefore, it has been suggested to focus on the ongoing management of performance measurement systems, or on the forces that have an impact on their evolution (Waggoner, 1999; Kennerley, 2002; Kennerley, 2003). Moreover, it has been proposed to further examine the frequency of the evaluation and re-evaluation of the SC performance metrics Bourne et al. (2002). Third, the literature lacks empirical studies examining the factors influencing the success and failure in the implementation of the SC performance measurement systems Bourne et al. (2002). Only a few studies have provided this empirical evidence, as for example (Bititci, 2005) and (Nudurupati, 2005). This point is however considered to be very important, because the failure rates in the implementation have been estimated at 70%. Specifically in the SC literature there has been little research describing the implementation. Fourth, the benchmarking of the performance of SCs is rarely found in the literature, even though the importance of the competitors has been highlighted (e.g. Beamon, 1999). The existing studies have been usually conducted in a single country and within a specific industrial sector (e.g. Basnet, 2003). Therefore, there the need for international benchmarking of supply chain performance has been proposed in order to make comparisons among different countries and various industries. Finally, only few research studies have examined the benefits versus costs in the implementation of SC performance measurement systems. Especially in case of small companies this can be quite important, as these may not have money, time or information to carry out the analyses required in order to improve their SC activities (Morgan, 2004). Morgan even argues that larger companies themselves may even need to develop the capabilities of their suppliers in order to be able to implement meaningful performance measurement systems.

2.4 Introduction of balanced scorecard in performance measurement of manufacturing supply chain

The need of performance measurement systems at different levels of decision-making, either in the industry or service contexts, is not something new (Bititci, 2005). Kaplan (1992) has proposed the balanced scorecard (BSC), as a means to evaluate corporate performance from four different perspectives: the financial, the internal business process, the customer, and the learning

and growth. Their BSC is designed to complement ‘‘financial measures of past performance with their measures of the drivers of future performance’’. The name of their concept reflects an intent to keep score of a set of items that maintain a balance ‘‘between short term and long term objectives, between financial and non-financial measures, between lagging and leading indicators, and between internal and external performance perspectives’’. The early image of the BSC serving the CEO like a control panel serves an aircraft pilot seems to have expanded to include mechanisms to alter the course of action as well. Now, the BSC seems to serve as a control panel, pedals and steering wheel (Malmi, 2001). **Table 2** outlines the four perspectives included in a BSC.

Table 2
The four perspectives in a balanced scorecard (Kaplan, 1992):

1. Customer perspective (value-adding view) Mission: to achieve our vision by delivering value to our customer
2. Financial perspective (shareholders' view) Mission: to succeed financially, by delivering value to our shareholders
3. Internal perspective (process-based view) Mission: to promote efficiency and effectiveness in our business processes
4. Learning and growth perspective (future view) Mission: to achieve our vision, by sustaining innovation and change capabilities, through continuous improvement and preparation for future challenges

The process of formulating a BSC begins when senior managers define the company's strategy. Spending time at the beginning to create a consistent understanding of strategy ensures that each measure ultimately incorporated into the scorecard emanates from a company's strategic goals and subsequently drives the realization of those goals. It is dangerous to assume that a common perception already exists regarding a company's strategy, as this can lead to an incoherent measurement system that pulls the organization in opposing directions (Brewer, 2000).

Once the strategy is clearly understood and articulated, the next step is to translate it into a set of performance measures. The balanced scorecard framework created by Kaplan and Norton suggests that balance is obtained by adopting performance measures from four different areas. As shown in **Table 2** and **Figure 1**, these are the customer perspective, the internal business process perspective, the innovation and learning perspective, and the financial perspective. This framework balances the inclination to overemphasize financial performance by incorporating metrics related to the underlying drivers of long-term profitability, namely, business process measures, innovation and learning measures, and customer satisfaction measures (Brewer, 2000).

The customer perspective asks for customer's opinion. They can be general, such as those focusing on customer value, and customer retention, or they can more specifically address a dimension of customer value such as product and service quality, response time, flexibility, or cost. The internal business process perspective asks what must be done internally to meet and exceed the customers' needs. The predominantly nonfinancial measures used here tend to focus on four types of performance attributes: (1) quality-oriented measures, such as scrap rates or "parts per million" defect rates; (2) time-based measures, such as throughput time or cycle time; (3) flexibility-oriented measures, such as changeover times or yield uniformity across a range of products; and (4) cost measures, such as no value-added costs or cost per unit of production. The innovation and learning perspective asks what needs to be done on a continuing basis to delight and retain customers. The focus is on the future as opposed to current capabilities. Measures tend to relate to such issues as new product development cycle time, percentage of sales from new products, and process improvement rates. Also, this is the segment of the scorecard in which companies tend to incorporate human resource management measures, thereby recognizing that people are the true drivers of innovation and learning. Finally, rather than reply solely on leading indicators of performance that are process oriented and nonfinancial in nature, the scorecard recognizes that ultimately companies must succeed in that all-important lagging indicator, the financial perspective. The financial perspective can be conceptualized as a system of checks and balances. Success in terms of the three other perspectives does not guarantee financial success. In other words, when financial success does not materialize despite glowing nonfinancial performance, that is a signal of flawed strategy, and senior-level managers need to rethink the

company's perceived source of competitive advantage, or of flawed understanding about which nonfinancial indicators drive financial success (Brewer, 2000).

These four perspectives of the BSC are applied to these discussed metrics or in another words the different metrics are fitted into four different perspectives of BSC as shown in **Tables 3–6**. Each of the four perspectives should be translated into corresponding metrics and measures that reflect strategic goals and objectives. The perspectives should be reviewed periodically and updated as necessary. The measures included in the given BSC should be tracked and traced over time, and integrated explicitly into the strategic SCM process (Rajat, 2007).

Table 3 (Rajat, 2007)

Performance metrics for the financial perspective:

1. Customer query time
2. Net profit vs. productivity ratio
3. Rate of return on investment
4. Variations against budget
5. Buyer–supplier partnership level
6. Delivery performance
7. Supplier cost saving initiatives
8. Delivery reliability
9. Cost per operation hour
10. Information carrying cost
11. Supplier rejection rate

Table 4 (Rajat, 2007)

Performance metrics for the customer perspective:

1. Customer query time
2. Level of customer perceived value of product
3. Range of products and services
4. Order lead time
5. Flexibility of service systems to meet particular customer needs

6. Buyer–supplier partnership level
7. Delivery lead time
8. Delivery performance
9. Effectiveness of delivery invoice methods
10. Delivery reliability
11. Responsiveness to urgent deliveries
12. Effectiveness of distribution planning schedule
13. Information carrying cost
14. Quality of delivery documentation
15. Driver reliability for performance
16. Quality of delivered goods
17. Achievement of defect free deliveries

Table 5 (Rajat, 2007)

Performance metrics for the internal business perspective:

1. Total supply chain cycle time
2. Total cash flow time
3. Flexibility of service systems to meet particular customer needs
4. Supplier lead time against industry norms
5. Level of supplier's defect free deliveries
6. Accuracy of forecasting techniques
7. Product development cycle time
8. Purchase order cycle time
9. Planned process cycle time
10. Effectiveness of master production schedule
11. Capacity utilization
12. Total inventory cost
13. Incoming stock level
14. Work-in-progress
15. Scrap value

16. Finished goods in transit
17. Supplier rejection rate
18. Efficiency of purchase order cycle time
19. Frequency of delivery

Table 6 (Rajat, 2007)

Performance metrics for the innovation and learning perspective:

1. Supplier assistance in solving technical problems
2. Supplier ability to respond to quality problems
3. Supplier cost saving initiatives
4. Supplier's booking in procedures
5. Capacity utilization
6. Order entry methods
7. Accuracy of forecasting techniques
8. Product development cycle time
9. Flexibility of service systems to meet particular customer needs
10. Buyer–supplier partnership level
11. Range of products and services
12. Level of customer perceived value of product

Several issues related to BSC have been discussed so far, which was mainly the framework, content and conception of BSC. However, how can we build up a good BSC to individual company's SC? In order to put the BSC to work, companies should setup goals for time, quality, performance and service and then translate these goals into specific measures. Companies should stop only focusing on financial measures but also combination of operational measures for business operations too (Rajat, 2007).

In building a company specific balanced SCM scorecard, following steps are recommended (Rajat, 2007):

1. Create awareness for the concept of balanced SCM scorecard in the organization
2. Collect and analyze data on the following items:

- Corporate strategy, business strategy and SCM strategy
- Specific objectives and goals related to corporate strategy, business strategy and SCM strategy
- Traditional metrics already in use for SCM evaluation
- Potential metrics related to four perspectives of BSC

3. Clearly define the company specific objectives and goals of the SCM function for each of the four perspectives

4. Develop a preliminary balanced SCM scorecard based on the defined objectives and goals of the enterprise and the approach outlined in the paper

5. Receive comments and feedback on the balanced SCM scorecard from the management, and revise it accordingly

6. Achieve a consensus on the balanced SCM scorecard that will be used by the organization

7. Communicate both the balanced SCM scorecard and its underlying rationale to all stakeholders

The metrics included in the balanced SCM scorecard should meet three criteria. They should be quantifiable, easy to understand, and ones for which data can be collected and analyzed in cost-effective manner. It is recognized that certain aspects do not have metrics that can be measured in quantitative terms. In such cases, it will be significant to relate these aspects to other ones that can be quantifiable (Rajat, 2007).

Kaplan and Norton (1996) also stress the importance of adhering to three principles in order to develop BSC that is more than a group of isolated and eventually conflicting strategies and measures:

- Build in cause-and-effect relationships

- Include sufficient performance drivers
- Provide a linkage to financial measures

Rajat and Milind (2007) mention that a strategy is a set of assumptions about cause-and-effect. If cause-and-effect relationships are not reflected in the BSC, it will not translate and communicate company's vision and strategy. These cause-and-effect relationships can involve several or all four of the perspectives in the BSC framework. For example, flexibility of service systems to meet particular customer needs (internal business operations perspective) will be more likely to meet customer expectations (customer perspective). Higher level of customer expectations will lead companies to supply more innovative products and services (learning and growth perspective). This in turn will increase the market share and profitability (financial perspective). A well-built BSC will include an appropriate mix of outcome measures and performance drivers. Outcome measures like total SC cycle time without performance drivers like buyer–supplier partnership level do not communicate how the outcomes are to be achieved. Furthermore, performance drivers without outcome measures may enable the achievement of short-term operational improvements, but will fail to reveal whether the operational improvements have been translated into enhanced financial performance. A company may invest resources significantly in maintaining buyer–supplier partnership and coordination in order to improve day-to-day business operations. If, however, there is no outcome measure for buyer–supplier partnership (e.g. faultless deliveries), it will be difficult for companies to determine whether their strategy has been effective. Outcome measures are more or less generic, but performance drivers are more company-specific and will often be based on the particular strategy that is being pursued. The ultimate aim of a balanced SCM scorecard will be to support management in a manner that improves the overall financial performance of the enterprise. ''A failure to convert improved operational performance into improved financial performance should send executives back to the drawing board to rethink the company's strategy or its implementation plans'' (Kaplan, 1996). Further, we must continuously keep in mind the fact that measurements are not enough, since they must be used and acted upon by the management. The BSC is not only an operational tool, but it can also be the foundation for strategic management system (Rajat, 2007).

2.5 Research concerning BSC in performance measurement of manufacturing supply chain

In the previous section I addressed SCM, performance measurement in SCM and BSC in performance measurement of SCM. All of the works which I have reviewed are related to SCM, performance measurement, but only some of them go into a greater detail of performance measurement of SC while used BSC. For instance, "Measuring Supply Chain Performance: Current Research and Future Directions" (Shepherd, 2006), "Measuring supply chain performance" (Beamon, 1999), "Using the balanced scorecard to measure supply chain performance" (Brewer, 2000), "Analyzing supply chain performance using a balanced measurement method" (Hans-Jörg, 2002).

Now, I will focus in detail on 2 research studies which applied similar methodologies in order to examine performance in manufacturing SC.

In "Using the balanced scorecard in assessing the performance of e-SCM diffusion: A multi-stage perspective", Electronic supply chain management (e-SCM), a specific form of inter organizational systems, has generally been regarded as one of the major strategies to create competitive advantage. The diffusion of e-SCM among trading partners is critical for its final successful use and accordingly, performance impact. However, the diffusion process is complex and dynamic in nature and involves an evolutionary property across time. Innovation diffusion Theory (IDT) is defined for effectively exploring diffusion process with multiple stages. Moreover, prior studies have found inconclusive results of IT-enabled performance due to inadequate measures. The balanced scorecard (BSC) with the extension to SCM, incorporating four performance perspectives, is appropriate for overcoming this problem. Grounding on the IDT and BSC, this study proposes a novel framework for exploring the relationships between a stage-based structure and the BSC. Data are collected from a questionnaire survey. The results indicate that there are significant differences between external diffusion and the two earlier stages, adoption and internal diffusion, on the four BSC perspectives. Furthermore, all of the four perspectives are well realized at external diffusion stage. Implications for managers and scholars are discussed (Ing-Long, 2012). Based on the literature review and hypotheses development which chooses e-SCM three stages model (Adoption, Internal diffusion, external diffusion), this

research also chooses company attributes by industry type and size. Four hypotheses are implemented based on BSC four perspectives (Learning and Growth, Business Process, Customer, Finance). First, a survey is well designed to collect empirical data; the survey instrument contains a three-part questionnaire, as below:

Part I. Basic information

1. Industry type_____.
2. Annual revenue (NT$ millions):
   ☐Less than 1000M ☐1000~10000M ☐10000~100000M ☐Greater than 100000M
3. Number of employees (Persons):
   ☐Less than 1000 ☐1000~5000 ☐5000 ☐Greater than 10000
4. Total number of suppliers_____.
5. Working experience:
   ☐Less than 5 years ☐5~10 years ☐ 10~20 years ☐Greater than 20 years
6. Education level: ☐High school ☐College ☐Graduate college ☐Ph. D. ☐Other
7. Gender ☐ Male ☐ Female
8. Age _____.
9. Position _____.

Part II. E-SCM diffusion

1. Adoption

My firm considers using digitally enabled SCM to improve logistics.
My firm considers using digitally enabled SCM to improve productions or operations.
My firm considers using digitally enabled SCM to increase sale revenue.
My firm considers using digitally enabled SCM to increase market share.
My firm considers using digitally enabled SCM to improve coordination with customers and suppliers.

2. Internal diffusion

My firm has used digitally enabled SCM in supportingaccounting management.
My firm has used digitally enabled SCM in supporting product or service delivery management.
My firm has useddigitally enabled SCM in supporting warehousing and inventory management.
My firm has used digitally enabled SCM in supporting productions or operations management.
My firm has useddigitally enabled SCM in supporting order processing management.

3. External diffusion

The proportion to which total suppliers of my firm have interacted with other firms through digitally enabled SCM.
The proportion to which total transactions of my firm with suppliers are done through digitally enabled SCM.
The proportion to which total interactions of my firm with suppliers are done through digitally enabled SCM.

Part III. Organizational performance

For basic information, this part collects the information about organizational and respondent's characteristics. The former includes industry type, annual revenue, number of employees, and number of supplies. The latter includes working experience, education level, and position.

For e-SCM innovation diffusion, it measures the extent of the three stages in diffusion e-SCM, adoption, internal diffusion, and external diffusion.

For organization performance, this part measures the four performance perspectives of the BSC, that is, finance, customer, business process, and learning and growth. The four perspectives first identify their objectives/sub-constructs and then develop their measuring items from an extensive literature review. As a result, the financial, customer, business process, and learning and growth constructs comprise 7 items, 8 items, 17 items, and 6 items, respectively.

For the moderating variable, industry type was defined to include three types of industries, that is, high-tech manufacturing, traditional manufacturing, and service. Company size was also measured using total number of employees in a company. It consists of three types of company size, that is, large size, medium size, and small size.

This study primarily explores the performance impact of e-SCM diffusion in organizations. The qualified companies for this study require an emphasis on investments in SC technologies and have considerable experience in SCM practice. Thus, it is assumed that larger companies would be more likely to have these experiences. A sample frame was assembled from the 2009 listing of manufacturing and service companies published by the Taiwan Stock Exchange Corporation, which contains 1000 manufacturing and 500 service companies. Furthermore, 600 manufacturing and 250 service companies were randomly selected as the study sample from this source. The target respondents for this survey would be the top managers, including general managers, vice general managers, or logistics/purchase executives in SCM division. These people are more likely familiar with the issue of e-SCM and its performance impact. The names and addresses of the top managers for the companies have been made publicly on their web sites. A survey method was used for this study. This survey was conducted during the period of April–June in 2009. First, the questionnaire with a returned envelope was mailed to one of the top managers for each company, and each company only received one questionnaire. Furthermore, in order to improve survey return, follow-up procedure was carried out by mailing reminders for non-respondents after 2–3 weeks (Ing-Long, 2012).

After data collection, hypotheses testing were implemented. The results show that the three diffusion stages indicate different impacts on the four performance perspectives. In particular, significant differences have been reported between the final stage (external diffusion) and the

two earlier stages (adoption and internal diffusion). Furthermore, the four performance perspectives are well realized at external diffusion stage. First, the issue on e-SCM diffusion has been particularly external focus on the collaboration among trading partners. Time-lag effect is the important determinant for effectively measuring organizational performance, in particular, customer and financial performances. In general, this can also provide insight to IT productivity paradox for effectively designing implementation program of technology innovation. This may be the major contribution of this research (Ing-Long, 2012).

In "Performance measurement in supply chain entities: balanced scorecard perspective", for the research methodology in this literature, using the framework of the BSC's four perspectives, 15 generic performance measures were incorporated. As many companies do not wish to reveal information concerning performance, they asked their respondents whether they measured such performance elements, whether it was important, and the percentage change compared to the previous year. The questions developed for the survey were derived after studying the process and formulation of the BSC which was carried out in another study on the adoption and formulation of the BSC in logistics companies. They also asked the respondents to denote the importance of each indicator was important to them, on a seven-point scale (1 = not important at all, 7 = very important). The third question required the respondents to put down the percentage change of each indicator as compared to the previous year's performance (Adrien, 1999).

For the sampling frame, the survey population for this study includes organizations in logistics, manufacturing, IPOs and retailing, they wanted to view performance measurement as perceived by different clusters of entities. And the total sampling frame comprised 652 companies. About the return rate, 113 useful filled out questionnaires were finally returned, giving a response rate of 17.33 percent. These results were gained after 3 rounds of phone calls.

After the collection of sample of 113 respondents, it was found that despite the need to provide a balanced approach to performance measurement; these responding companies are still focusing primarily on traditional measures such as gross revenue, profit before tax. From a SC perspective, the non-tangible logistics performance indicators such as on-time delivery, customer satisfaction,

and cost reduction are perceived to be most important but they are not the most measured of the indicators (Adrien, 1999).

The results further suggest that managing a given SC's overall performance necessitates the coordination of measures across the different entities on the SC. In essence, this requires all entities on the SC to adopt a common balanced perspective in their performance measurement and management in order to facilitate the overall performance and competitiveness of the entire SC (Adrien, 1999).

The results also concur with (Norreklit, 2008) in that there are clear and obvious pitfalls when measuring the performance of a company, even in applying the BSC perspective. While financial measures are critical in determining the failure and success of a company, these are not holistic enough to ensure long-term sustainability of the company especially in the light of the current climate of ecological and social responsibility. The BSC approach should never be applied as a method to justify the financial performance of a company at the expense of the other less tangible but equally significant measures such as employee retention.

They also mentioned that this study could be extended to other countries in the surrounding Asian region, thus making a comparative study possible. Further, the study could be enabling a longitudinal analysis of the SC clusters over time. The results collected over time could also be used as benchmarks to the SC entities in Singapore, and such benchmarks may then be evaluated (Adrien, 1999).

2.6 Other popular performance measurement models

I already addressed BSC model more in detail, but in over 50 literatures which have been reviewed, there are also other popular models which have been implemented in real world. Here, I want to discuss the most popular ones which are the Supply Chain Operations Reference (SCOR) model and Total Quality Management (TQM) model.

2.6.1 The supply chain operations reference (SCOR) model

The Supply Chain Operations Reference (SCOR) model released by Supply Chain Council (SCC) in 1996 has been widely studied and used in research and industry. Researchers and practitioners have found the SCOR Model which is a good reference that integrates most of the business processes of an organization in a cross-functional framework. SCOR is based on five distinct management processes, namely Plan, Source, Produce, Deliver and Return. These five processes form the top level of the SCOR model. Each process is further decomposed into lower levels (Chen, 2007).

SCOR is developed as a cross-industry standard for SCM. It uses a process reference model to explain a SC. The process reference model is a combination of business-process reengineering, benchmarking and best practices analysis. The process reference model is aimed at providing a framework for performance measures and best practices for standard processes. SCOR apply interactions with customers/markets and transactions with products. SCOR is based on management processes like plan, source, make, deliver and return. It actually defines the SC as an integrated process of these management processes. It gets activated from the stage of supplier's supplier up to customer's customer. It is aligned with operational strategy, material, work and information flows. Thus SCOR enables communication among SC partners. The heart of the SCOR system is a pyramid of four levels that represent the path a company takes on the road to SC improvement. The pyramid can be seen in the **Figure 2**. The top level defines the scope and content for the model and sets the basis for performance targets. Configuration level configures the SC so that the operational strategy can be implemented. The third level e.g. the process element level consists of process element definitions, information inputs and outputs, performance metrics, best practices and system capabilities to support best practices. The implementation level is concerned with defining practices to achieve competitive advantage. SCOR thus provides list of performance measure for each activity and process in a SC, aligns these measures with the strategic objectives and provides the best practices for each measurement. It is therefore used to describe measure and evaluate SC (Ambuj, 2012).

The SCOR model involves more than sixty process steps and more than two hundred metrics. While the Supply Chain Council indicates that the model can be used in almost every industry,

any SC from a simple supply chain network to a very complex one, the SCOR model is not easy to implement. In order to use the SCOR model effectively, managers need to examine and understand their companies' specific SC processes. Simply following all the processes and metrics listed in the SCOR model will not work for most companies. First, the SCOR model was originally designed mainly for the manufacturing industry, and so a large portion of the model is focused on three processes, "Make" (production), "Build-to-Order Product Source" and "Deliver" (Chou, 2004).

2.6.2 Total quality management (TQM) model

TQM is a philosophy, a set of guiding principles, and actions which compel an entire origination to excellence and efficiency in personal and corporate activities. It is the application of quantitative methods, technical tools, and management techniques to improve all the processes within an organization and continuously exceed customer needs (Chou, 2004).

According to (Besterfield, 2003), TQM requires six basic concepts:

1. A committed and involved management to provide long-term top-to-bottom organizational support
2. A focus on the customer, both internally and externally
3. Effective involvement and utilization of the entire work force
4. Continuous improvement of the business and production process
5. Treating suppliers as partners
6. Establishment of performance measures for the processes

Garvin (1988) identified eight dimensions of quality. The table below shows these eight dimensions with their meanings and explanations. These dimensions are partly independent, which means that a product or service can be excellent in on dimension and average or poor in another.

Table 7: Eight Dimensions of Quality

Dimensions	**Meaning and Example**
Performance	Primary operating characteristics of a product or service, such as the service speed in the fast food industry
Features	Secondary characteristics, added features that supplement the product's/service's basic functioning. One example is free drinks on a plane flight
Conformance	The degree to which a product's/service's design and operating characteristics meet pre-established standards. One common measure is the frequency of repairs under warranty
Reliability	Consistency of performance over time. Among the most common measures of reliability are the mean time of first failure, the mean time between failures, and the failure rate per unit time
Durability	Product useful life, including repair. One example is estimated product lives for refrigerators
Serviceability	Resolution of problems and complaints: the speed, courtesy, competence, and ease of repair. One example is the timeliness with which service appointments are kept
Aesthetics	Sensory characteristics: how a product looks, feels, sounds, tastes, or smells
Perceived quality	Past performance and other intangibles, such as images, advertising, brand names. Reputation is on the primary contributors to perceived quality

2.7 Research gaps in performance measurement of manufacturing supply chain

Above content gives a brief view of current situation of performance measurement of manufacturing SC. There are some research gaps which are valuable to mention:

1. Based on most of the research papers which have been reviewed, they only focus on their company's SC, they did address the whole SC based concept (e.g. Basnet, 2003; Barbara Bigliardi, 2010), as a typical model which includes supplier, manufacturer, distributor and retailer

2. Because different types of manufacturing SCs require specific performance measurement system, it is very difficult to create a general approach which can be applied on all types of manufacturing industries and no literatures mentioned it

3. Most of the research works focus only on a specific country and on a specific market sector (e.g. Basnet, 2003; Barbara Bigliardi, 2010). There is a need for international benchmarking of SC performance, across countries and different market sectors

4. There are some studies which did surveys for data collection of performance measurement research within manufacturing SC. But collected data are limited because of the creation of items of questionnaires (e.g. Ing-Long , 2012; Basnet, 2003)

5. Most of the research studies which have been reviewed only apply four perspectives from BSC model (e.g. Rajat , 2007; Barbara, 2010)

6. Most works which have been reviewed do not discuss the weightings of different metrics in order to measure manufacturing SC performance (e.g. Hans-Jörg Bullinger, 2002; Brewer, 2000)

3. Objective

My research was inspired by BSC concept and also from my working experience, because I was dealing with international electronics' SCs, and there was no performance measurement system to measure the SC performance in these SCs. From here came an idea which to motivated me to

develop a simple, practice and comprehensive tool which can measure SC performance. The thesis has 2 main objectives:

1. **To develop a new methodology for the performance measurement of manufacturing SC.** It was determined that the methodology should be generic, comprehensive, simple but still capturing well the importance of the criteria. Each of these characteristics are discussed below:

- The proposed methodology should represent a generic approach, i.e. the developed tool should be effective when applied to a wide range of manufacturing SCs. Also, this methodology is not limited geographically; it can be applied in any country or region. These characteristics will greatly increase the applicability and usefulness of the methodology.

- Another important characteristic of the methodology is its simplicity. In order for the companies to regularly use an assessment tool it should be relatively simple. For example, SCOR model may be the most popular model which has been applied to a mount of manufacturing SCs, but normally the number of attributes is over 200 and they are not fixed. It will be very difficult to handle those values even using advanced IT solutions. BSC, on the other hand, usually involves less attributes, but the attributes are not fixed. BSC does not give specific attributes in each perspective, and companies need to choose or create by themselves according to their business goals or requirements. My objective is thus to develop a simple methodology compared to these methodologies, with a hope that it may be easily applied in the real life.

- As discussed above, most of the tools proposed in the literature do not take into consideration weights of various metrics and indicators. For example, BSC or SCOR do not incorporate the weights for the various attributes. Because you cannot know which attribute is more important and which one is less important for measuring the SC performance without weights. The introduction of weights for the attributes should allow capturing the importance of each criterion for each specific SC. These weights should therefore be one of the important features of the methodology.

2. **To evaluate manufacturing SC performance and carry out a comparative analysis of existing SCs.** Here, 3 sub-objectives were determined as follows:

- To analyze the general status of performance measurement of manufacturing SCs based on the globally collected data.

- To evaluate weighted performances of manufacturing SCs based on 4 factors: Evaluations and comparisons will be performed based on different industries, different countries, based on the adherence of the companies to a strategic alliance and based on the use of the performance measurement systems in the companies.

- To determine the most important attributes for each compared group (heavy versus light industry SCs, national versus international SCs, SCs with and without strategic alliance, SCs using and not using the performance measurement systems)

4. Methodology

4.1 Tool development

In this part, I will introduce the development process of this tool in details within 2 parts, first is the importance of attributes, there are totally 23 attributes in this part within 4 different perspectives. The objective in this part is to gain different values of importance weights for each attribute. The second part is the status of attributes; there are also totally 23 attributes in this part within 4 different perspectives. The objective in this part is to gain values of current performances for each attribute.

As it was decided, this tool should be a very simple tool to use; it should be easy to apply to the whole manufacturing SC. After consideration, 23 attributes have been selected. It was decided that for any manufacturing SC, a little more over 20 attributes should not be that difficult and time consuming to apply.

This tool should be also a comprehensive tool, it should cover all elements of a manufacturing SC. It was therefore decided that 4 perspectives of this tool can accomplish this task within 23 attributes in details.

It is also should be a generic tool, therefore in the development process, I evaluated every single attribute in order to make sure each of them can be applied to all kinds of manufacturing SCs.

One of the characteristics of this tool is that it should be able to capture the different weights of importance for different attribute in the whole SC. In order to achieve this objective I developed the 1 to 5 scale system and applied the student T-distribution.

4.1.1 Development of importance of attributes

As I mentioned earlier, I want this tool can measure different attributes of the whole SC, and also their associated weights. 4 perspectives which are resource, customer-based interaction, SC-based interaction and flexibility have been developed in this tool, totally 23 different high level attributes have been given. There are 4 attributes in resource perspective, 8 in customer-based interaction perspective, 7 in SC-based interaction perspective and 4 in flexibility perspective. I will discuss the reasons to develop these 4 perspectives in details, the first perspective is resource, as we can see, resource is a very typical and important perspective, because resources are the fundamentals for any manufacturing SCs, without materials, no manufacturing SCs can exist. Resource is also an important perspective which has been mentioned in (Beamon, 1999), I agree with Beamon's opinion here and define resource as the first perspective. The fourth perspective which is flexibility is developed by my working experience, I saw the real performances for my company's SC against some emergencies such as customer's large amount of orders and I thought it is a very good perspective to measure the SC's performance. It can be also found in some literatures (e.g. Beamon, 1999). As we know in BSC model, there are total 4 perspectives which are financial perspective, customer perspective, internal business perspective and innovation and learning perspective. Because the scope of BSC is not based on the whole manufacturing SC, some behaviors of SC are lost in these 4 perspectives, for example, SC-based interaction, it covers all the activities inside the whole SC, but BSC model cannot cover them

well. That is the reason I developed SC-based interaction and customer based interaction perspectives. From these 2 perspectives, all the interactive behaviors of SC can be covered easily.

Table 8

Perspectives	**Number of attributes**
Resource	4
Customer-based interaction	8
SC-based interaction	7
Flexibility	4
Total: 4	Total: 23

To talk about the framework of this tool, there are 5 options which can be chosen by users. It is a scale of importance composing of 5 options, numbering from 1 to 5; they are unimportant, slightly important, important, highly important, and critically important. User can choose the suitable importance level based on their SCs. I also put a N/A as an option in this part in case.

Table 9

Option	**Comment**
1	Unimportant
2	Slightly important
3	Important
4	Highly important
5	Critically important
N/A	Not applicable

There are 4 attributes in resource perspective, as I mentioned earlier, resource is the basis of manufacturing SC, it is vital for measuring performance of manufacturing SC, it is related to cost, waste and some other points shown in **Table 10**.

Table 10

Resource Perspective	**Comment**
Minimization of cost	Financial measure is always first priority in most performance measurement systems, I put this attribute as first one
Minimization of waste	There are different types of wastes among a manufacturing SC such like manpower, materials
Environmental friendliness	As long-term sustainability of the manufacturing SC especially in the light of the current climate of ecological and social responsibility and conscious carbon emitting becomes more and more important. This attribute is chosen
Efficient utilization of resources	Efficiency is significant to any kind of SC

In customer-based interaction perspective, all attributes are chosen from customer based scope, it means the attributes are associating within two companies, one of them is treated as the other's customer. For example, the end-user can be the customer of a retailer. But the retailer can be customer of a distributor at the same time. The relationship looks like a chain. All the activities between these 2 entities should be measured.

Table 11

Customer-based Perspective	**Comment**
Fulfill rate	Developed by working experience and literature review (e.g. Benton, 2005;Gunter,
Warranty return rate	
Number of shipping errors	
Customer satisfaction	
Number of successful on time deliveries	

Impact of power on business relationship	2006)
Implementation of customer's future strategic needs	
Customer loyalty	Developed by interviews

In SC-based interaction perspective, I chose the attributes which are all interacted with each other among a scope of whole SC, the interaction can happen within an entity like a company or it can happen among different entities. These 2 kinds of interactions have to be measured to cover all the behaviors inside an entity or among different numbers of entities.

Table 12

SC-based interaction Perspective	**Comment**
Uniformity of systems within the company	Developed by my working experience, (e.g. standard operation procedure (SOP) is highly applying on production line in order to standardize the operators' operation on producing products)
Uniformity of systems among the organizations	Developed based on the above. As we may see that more and more companies are trying to apply same ERP systems through their SCs in order to gain better uniformity of systems, I developed this attribute as a very new measurement towards manufacturing SC
Information sharing capability within the company	Developed by working experience and literature review (e.g. Benton, 2005; Christopher, 2000)
Information sharing capability among the organizations	
Trust within the company	We may see trust as an attribute to be discussed a lot in some literatures (e.g. Gunter, 2006; Chan F. , 2003), but none of them discussed it

Trust among the organizations	into details. Here, I put attributes of trust within the company and trust among the organizations into this perspective, it was also agreed with one of the 5 professionals when we took an interview
Coverage of organizations in strategic alliance	Because strategic alliance becomes more and more important as it represents the cooperation among SC organizations, a better work flow can be gained through a better coverage of the alliance

The fourth perspective is flexibility of manufacturing SC, which will try to measure the potential capability of an individual manufacturing SC. The flexibility has been already proposed in the previous research (Beamon, 1999). This is a very important perspective, because it can measure the capability of a whole SC and how much pressure it can deal with. As we know, nowadays, things are changing very quickly and manufacturing SCs are in a dynamic environment. It is common to see some emergencies happening within SCs. SCs should have some abilities to deal with them in order to survive in the market. After lots of discussion and consultation with industry professionals, finally, 4 attributes are chosen:

Table 13

Flexibility Perspective	**Comment**
Flexibility in production volume	Developed by working experience and literature review (e.g. Beamon, 1999;De Toni, 2001)
Flexibility in time of delivery	
Flexibility in changing the variety of products produced	
Flexibility in introducing new products	

4.1.2 Development of status of attributes

As discussed previously, the purpose of the second part is to capture the performance of the specific SC of the user. All the attributes in this part are in fact the same as in the part assessing the importance of attributes, i.e. we have again 23 attributes here. The framework is similar as it is in the previous part related to the importance of attributes, only with a slight modification of the scale. The scale has changed to 1 to 5, where 1is the worst status to 5 which is the best status. The users can select the suitable level based on their current status of their whole SCs depending on each attribute. Moreover, I was concerned that some users may not be able to evaluate quite accurately the performance of each attribute, because they may come from a variety of departments. Therefore I decided to include an option "I don't know" into the option list. Also, I have added "N/A" into the option list in case it cannot be applied to some SCs

Table 14

Option	**Comment**
1	Worst status
2	-
3	-
4	-
5	Best status
I don't know	-
N/A	Not applicable

4.2 Tool validation

4.2.1 The interview with statistical analysis expert

As I discussed in details above concerning the development of this new tool, at the beginning stage of the development, it was only based on my working experience and literatures which have been reviewed, as I only have the experience dealing ODM laptop SCs, I have knowledge

concerning electronics SCs, but as I mentioned early in this research, I want to develop a general approach in order to apply to all kinds of manufacturing SCs and also my opinion is subjective. It can be verified by interviews with industry professionals, and they should be from different industries instead of only one specific industry in order to validate this tool.

The number of necessary interviews which would validate the tools has been discussed with a statistical analysis expert whose name is Mr. Carl St-Pierre from Ecole Polytechnique. It is confirmed that 5 to 10 interviews can validate this tool.

4.2.2 The interviews with 5 professionals from different industries

The next step involved finding the professionals from various SCs which would be willing to be interview. When there was an opportunity to join an annual event of American Society of Quality (ASQ) in HEC Montreal, I registered this event and went to HEC Montreal to participate in it. This way I got a lot of opportunities to talk with quality professionals from a variety of backgrounds, and I got the chance to know a few senior experts who are working in manufacturing fields. Also, since Linked-In as a professional social networking tool has become very popular among professionals, I became also a member in hope to find some suitable interviewees. I even paid to upgrade my membership to the highest level, which allowed sending more in-mails to invite more members. Further than finding suitable interviewees through events and online, I even contacted my networks in China as the manufacturing industry in China is developed. My effort was paid back well; finally, I invited 2 professionals from the ASQ event, 1 from Linked-in and 2 from my networks in China. These 5 professionals are from 5 different industries as I expected:

The first interview I took is with Ms. Sandra Lafleur who is a Linked-in member and also a senior buyer from Hector Larivee, Hector Larivee is a food service company, it is the No. 1 food service company in Quebec, it plays a role as distributor among its food SC and Ms. Lafleur takes the responsibility of sourcing raw materials. She invited me to take a business trip to her office which is located in Montreal, I went to her office which is also the distributor center and warehousing center of Hector Larivee, in 2 hours interview, she gave me lots of suggestions

concerning the framework, attributes for this tool, after that, she took me to visit her company, and told me a lot concerning her company's whole SC.

The second interview I took is with Ms. Veronica Marquez, Ms. Marquez is a certified lean Six Sigma Black Belt holder, also ASQ member and mentor. She has very rich working experience with logistics and SC operations. Now, she is working in CHEP international, CHEP international is a large international company and it has many branches including one branch in China, its Montreal office is located in Saint-Laurent area. CHEP is helping other companies to handle their logistics, they provide pallets service, especially have expertise in dealing with chemical materials. Its SC models contain B2B. Ms. Marquez is an Account Manager in CHEP and dealing with internal operations and logistics, external suppliers, such as carriers as well as customers to ensure satisfaction whole making processes as efficient as possible to reduce cost and eliminate waste. We took the interview in CIISE department of Concordia, in 2 hours interview, she gave me advice concerning this tool and research methodology.

The third interview I took is with Mr. Tao Liu, Mr. Liu is a Project Manager in MCC China, MCC China is a company in metallurgy industry, and they produce large instruments for producing metals. Mr. Liu is dealing with many suppliers for their production of instruments and their SCs also include B2B model, their customers are among the world especially in Europe. Because we are in different time zones and the long distance between us, I chose an online interview with him, I make an appointment with him then we took it.

The fourth interview I took is with Mr. Alex Zhao, Owner and General Manager of AVAN international. AVAN international is a private company which is dealing with plastic injection, and produces many plastic products for food industry. As the owner of AVAN, Mr. Zhao has 25 years working experience in plastic manufacturing field and also SC operations, he gave me very useful suggestions related to the attributes and data collection.

The last interview was taken with Mr. Mutair Kadiri, he is a Project Manager who is taking care of supplier performance management in Honeywell Aerospace, and he is ASQ-CSSBB and ASQ-CQE member. It is worth to mention that Mr. Kadiri's job function is to deal with suppliers'

performance; it is highly related to my research. We took the interview in CIISE department of Concordia.

To summarize, I took around 20 hours for these 5 interviews and for each about 2 hours. The interviews have been fully recorded and analyzed after that. The main conclusion of all the interviewed professionals was that this is an effective tool for measuring manufacturing SC.

4.3 Proposed application of the tool

The proposed tool has been developed as very practical and it is one of the hopes of this research that the tool can be used in the real industrial setting. As discussed previously, any manufacturing SC in any industry and any country can use it. It may be slightly modified to suit the specific SC features, but no special preparation is necessary in order to start using the tool. The simplicity of the tool will encourage the companies to adopt the tool. Here is the proposed application of the tool:

Representatives from each company within a specific manufacturing SC will be selected and they should have regular meetings where they would sit together and provide assessment with each attributes' status, and after enough data has been collected, the calculation will give the final value of performance for each perspective and attribute. I suggest that the tool can be applied every quarter and the results should be compared to the ones from the last quarter. This will allow an easy tracking of the performance of the SC. Through this method, companies in the whole manufacturing SC can note their weaknesses concerning perspectives or attributes, then, they can work on that to improve the performances in next quarter.

4.4 Development of questionnaire

After development of the tool, I need to evaluate the SCs and compare different SCs based on the 4 perspectives and 23 attributes. I need to get insight into a lot of SCs within a lot of industries

and a lot of countries, therefore in order to get the data, to take interviews is impossible or very difficult to achieve. A survey with questionnaires is decided in order to obtain enough data.

Therefore, I created the format and content of the questionnaire according to this tool. A survey was ongoing and questionnaires were distributed through online and over email, when data was collected, the calculation was applied to give results on specific manufacturing SC's performance across a variety of countries and industries. Based on the results, different SCs can obtain a good insight on their SC performance and improve those attributes with poor performance in future.

In the introductory part of my questionnaire I included apart from the usual information three important points. First of them was a figure which shows five typical organizations of a whole supply chain. They are supplier, manufacturer, distributor, retailer and end-user. It is not common to see a figure at beginning of a questionnaire. The reason is that my research is based on the whole SC concept, not a single company's SC. I want to make this very clear to the respondents that this is as a fundamental for my research, because any responses which evaluate attributes of single companies instead of the whole SCs would alter the results. I therefore further highlighted this point within a figure. I also included the comment as below:

"As indicated in the figure above, please pay attention that this questionnaire is based on the whole SC which includes your company. It is not based on your company's SC. If your company has headquarters and branches, please consider the one you are currently working in."

The second consideration was related to a confidentiality issue. Nowadays, the market competition is stiff. Some business information or data is very important and confidential for those companies. As a consequence, the companies may be reluctant to provide this information. However, obtaining the necessary data is critical for achieving the second objective of my thesis in order to be able to run the statistical analysis and make conclusions. I decided that I would reassure companies about the confidentiality of the information they will provide, and added explanation as below:

“Please notice that this questionnaire is highly confidential. We will not release your information to any other third party without your permission.”

Third, as mentioned above, obtaining sufficient amount of the data is crucial for this step. In order to increase the response rate I decided to include some motivation to encourage the respondents to fill out this questionnaire and sent it back to me. I thought to put 50 dollars firstly, but then I changed to put a mini-iPad as a gift, as it is a pure academic research, cash may let respondents feel uncomfortable and may refuse to fill out the questionnaire. After consideration with research budget, mini-iPad seems a best choice for this position:

“By responding to the questionnaire you will get an opportunity to be a randomly selected respondent who will win a mini iPad!”

The questionnaire has 4 parts as follows:

Part 1: Demographic Information
Part 2: General Information
Part 3: Importance of Attributes
Part 4: Status of Attributes

Each of these parts will be discussed in detail in the following sections.

4.4.1 Part 1: demographic Information

I created 13 questions in order to gain enough information concerning our respondents. Every question is designed technically.

Question 1 is to know respondent’s company’s industry, 12 typical manufacturing fields have been chosen, which are electronics, food, beverage, textile, mechanical, aerospace, chemical, metallurgy, automotive, pharmaceutical, construction, logistics. Since I may not have included all the possibilities I put a blank option at the end for the others.

Since my research scope is based on international SCs, not only local SCs, question 2 is concerning respondent's company's country. In order to know our respondent's company scale, question 3 asks number of employees in respondent's company. 11 options have been developed as: Less than 50, 50-100, 101-250, 501-1000, 1001-2500, 2501-5000, 5001-10000, 10001-50000, 50001-100000 and 100001 & above. If the number of employees in respondent's company can be gained, the different scales of SCs can be divided and the performance for different scales of SCs can be compared.

Question 4 is concerning the profits, it asks annual sales of respondent's company, 8 options have been developed as follow: Less than 1 million, 1-5 million, 6-25 million, 26-50 million, 51-100 million, 101-250 million, 21-0.5 billion, and 0.5 billion & above.

Question 5 asks concerning respondent's department, 11 options have been developed; which are Production, Quality Control, Technical Support, Logistics, HR, Finance, Marketing, Sales, RD, Sourcing, and Supply Chain. I put others as a blank for the respondent who does not find their specific answer among the ones above.

Question 6 asks respondent's company's role in their whole SC, without only choosing 4 typical organizations in SC. 7 options have been chosen; they are supplier, transporter, manufacturer, distributor, wholesaler, retailer, and customer. I put others as a blank for filling out.

Question 7 is concerning respondent's position in the company. The purpose of the question is to understand whether the respondent belongs to the senior level management. As my research is based on the whole SC, it needs a comprehensive knowledge about the business, which may be difficult to gain while working on some low level positions. 6 options have been provided to choose from, which are Owner, General Manager, Manager, Supervisor, Project Leader/Manager and Buyer. Again, I included the option "others" a blank space to fill out.

Question 8 is concerning respondent's working experience in the position. Again, this will help me understand whether the respondent may have gained sufficient knowledge to fill the

questionnaire. 8 options have been developed, they are less than 1 year, 1-2 years, 2-3 years, 3-4 years, 4-5 years, 5-10 years, 10-15 years and more than 15 years.

Based on the literature review (e.g. Benton, 2005; Kuo-Pin, 2010), strategic alliance is very important to a SC's success. It represents a cooperation and friendship level among SC organizations. Therefore, in question 9, a "YES/NO" question has been included to find out whether the respondent's whole SC has any strategic alliance.

Question 10 is based on the respondent's answer in question 9, if respondent answered "YES", they can choose the organizations belonging to the strategic alliance, which are supplier, transporter, manufacturer, distributor, wholesaler, retailer and customer. As previously, I included "others" as a blank space for specifying if none of the option applies. Here, you can see that instead of only putting retailer as an option, I added wholesaler, because they are similar but not same. I added customer as an option because B2B model is popular in some manufacturing SCs.

In order to identify whether the respondent's company's SC is part of a local SC or an international one, question 11 is developed to ask if the whole SC is within a same country or not. The question 12 is based on the answer provided in question 11, if the answer is "NO", the respondent can choose which organization is out of the country.

The last question in part 1 is question 13, which helps better identify respondent's SC scale. This question asks about the numbers of suppliers, manufacturers, distributors, retailers and customers in the whole SC. I was concerned that because my respondent is from only one company within the whole SC, he or she may be a senior engineer or manager, he or she may know the scale of those numbers, but not exact number. I put different ranges for each organization. As I mentioned before, some SCs involve B2B model. I put one option as "I don't know" for the respondent who has no idea concerning the numbers and one option as "N/A" for distributors, retailers and customers based on B2B model.

4.4.2 Part 2: general information

The purpose of the second part is to get some basic information concerning respondent's whole SC, for example, the knowledge of performance measurement for those respondents who are working on manufacturing SC daily, the implementation of performance measurement systems in those SCs and etc.

5 general questions have been developed; question 1 asks about respondent's view concerning performance measurement in their SCs. From strongly disagree to strongly agree, there are 1 to 5 scales for the respondent to choose the importance level of performance measurement in the whole SC.

Question 2 asks respondent whether the SC of his company has implemented any kinds of performance measurement systems in the whole SC. Here they can choose "YES" or "NO". Question 3 is based on the answer given in question 2, if the respondent chose "YES", they can choose performance measurement systems which have been implemented in the whole SC. 3 current most popular performance measurement systems are proposed as options; and these are BSC, TQM and SCOR. Aware that other possible systems may be in use I put "others" and a blank space to fill in case the respondent wants to share the name of the system.

Question 4 asks respondent about which aspect of the whole SC is the most important one to measure. After a long time consideration and discussion, 4 options have been developed, they are time, flexibility, reliability and cost. Some aspects like number of shipping errors and fulfill rate are not generic aspects, they are in detail level. Therefore, they are not added. Again, I included "other" as a blank for filling out if any other aspect is suggested by a respondent.

Question 5 asks respondent: "What are the main reasons which prevent the whole supply chain from implementing performance measurement systems?" The purpose is to understand why some SCs still do not implement any performance measurement systems 8 options are given as some common reasons as cost, manpower, time, lack of data, lack of interest, lack of management commitment, lack of priority among projects and lack of knowledge. I included a

"N/A" into this option list, because some respondents' SCs already implemented advanced performance measurement systems. As previously, I included "others" as a blank to let respondent to fill out if they have other reasons not listed.

4.4.3 Part 3 and part 4

Part 3 and 4 are also created according to the description in the tool development part. Part 3 is related to the importance of 23 different attributes, Part 4 is related to the status of 23 different attributes.

At the end of this questionnaire, I added three questions; in the first one I ask our respondents if they are interested in receiving the research summary. This may be interesting for certain companies. i assume that the fact that they spend time and filled the questionnaire is a certain proof that they are interested in the topic and may be glad to access the results of this study. I do plan to compile a summary of the thesis in a few pages and to send it to the interested respondents. The second question asked the respondents whether they want to be included in the draw to win the gift which is the mentioned mini-iPad. In the third question they are asked to leave their e-mail addresses if they want to get the above two items.

4.5 Distribution of questionnaire

The targeted recipients of the questionnaire are international professionals who are working in manufacturing SCs, In order to distribute the questionnaire among them I applied Linked-in again. I joined around 100 groups related to manufacturing SCs. This was not a simple task, as some groups are not open to public, and some groups may allow you to enter but after posting the questionnaire in the group they may review your postings and may refuse it. It took a considerable amount of time to post questionnaires in those groups. The other way was to distribute questionnaires was over email. I developed two formats of the questionnaire. The first one was an online version created by Google Doc. I have selected Google because it is known to have a very stable web server and it is very convenient to develop a questionnaire based on

specific requirements. The online version of the developed questionnaire can be found at below URL:

https://docs.google.com/forms/d/10LQAM8-JsfJKB2wT82PDGW4xELd7dO0alR3zDs8_tio/viewform?embedded=true"

The second format used was PDF (fillable) version of questionnaire. Although in most of the cases the web-based format is more convenient it was necessary to use the pdf format as well. The reason is that the collection of the responses residing in some countries (specifically in Iran) was difficult through the web-based version, because the respondents could not access the website.

5. Analysis of result

5.1 Analysis of data from part 1 and part 2 of questionnaire

After 6 months of running the survey, I obtained in total 311 responses, which after validation gave me 43 responses considered as useful data. The reason is that I found many of the responses are from unreliable resources, so I decided to not include them The percentage is 14%. Because some questionnaires were sent by friends, the total number of sent out questionnaires cannot be obtained. Therefore, I will not calculate percentage of response rate. Based on the 43 responses' data, it is enough to apply student-T distribution to calculate final needed values. I will provide analysis with some questions of the questionnaire of Part 1 and Part 2 as below:

- Does the whole supply chain have any strategic alliance?

Based on the 43 responses, 13(30%) SCs do not have any strategic alliances, 30(70%) SCs have strategic alliances. One of the reasons is that one of the purposes of building up strategic alliance is to share information, and sharing information can improve the performance of whole SC dramatically. Based on my research results, we can see that most SCs do have strategic alliances. The results are shown in **Figure 1**:

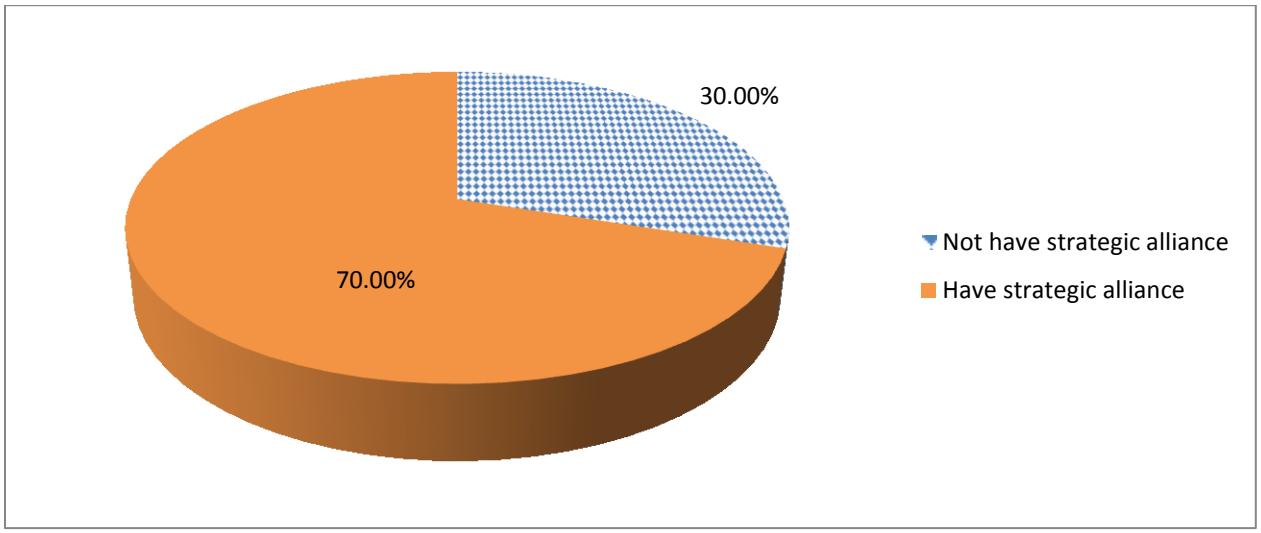


Figure 1: Strategic Alliance

- Is the whole supply chain all within a same country?

Based on the 43 responses, 9(21%) SCs are within same country and 34(79%) SCs are not within same country. In the 9 local SCs, 1(11.1%) SC is from Iran, 3(33.3%) SCs are from U.S., 2(22.2%) SCs are from Canada, 2(22.2%) SCs are from Brazil, 1(11.1%) SC is from Bangladesh. As we know the tendency towards globalization, more and more SCs are becoming international. Especially in case of large companies, it is very common that they may have some suppliers in foreign countries. This is supported by our result, which shows that a great amount of SCs are international SCs. The results are shown in **Figure 2**:

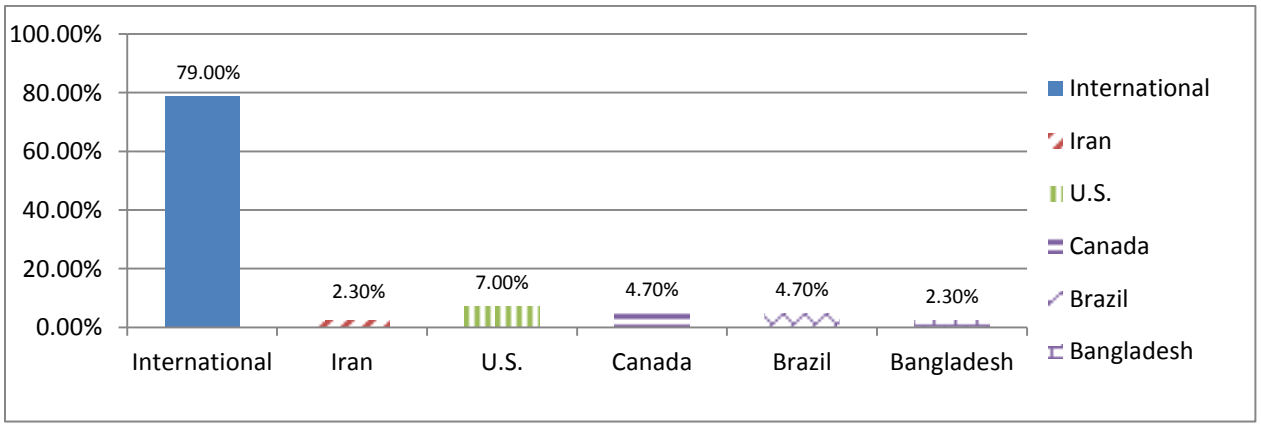


Figure 2: Distribution of Country

- Performance measurement is important in the whole SC

Based on the 43 responses, only 1(2.3%) respondent chose 1(strongly disagree), no respondent chose scale of 2, 1 (2.3%) respondents chose scale of 3, 11 (25.6%) respondents chose scale of 4, 30(69.8%) respondents chose scale of 5(strongly agree). Therefore, most of the respondents think performance measurement is important in the whole SC. This result was expected and the advantages of the performance measurement have been extensively discussed in the literature.

The information from the performance measurement is needed especially in top management level, but also several kinds of SCM measures are needed at every management and operational level. The management's main interest is to know how efficient the SMC is. Also several management levels are interested in knowing about SCM capability and performance. Performance measuring is also essential when the SC is developed. Performance measurement provides information on how effective the development work has been. In manufacturing companies performance measurement provides information for the monitoring, control, evaluation and feedback functions for operations management. When implementing and executing a new business strategy, the performance measurement provides important feedback about the improvement. Good performance measurement system also generates more open communication between people in organizations and in the network, and hence improves the performance (Waal, 2003; Kaplan., 1996; Lohman , 2004; Neely, 1994 ; Gunasekaran, 2007).

Gunasekaran & Kobu (2007) presented following purposes of a performance measurement system:

- Identifying success
- Identifying whether customer needs are met
- Better understanding of processes
- Identifying bottlenecks, waste, problems and improvement opportunities
- Providing factual decisions

- Enabling progress
- Tracking progress
- Facilitating a more open and transparent communication and cooperation, the results are shown in **Figure 3**:

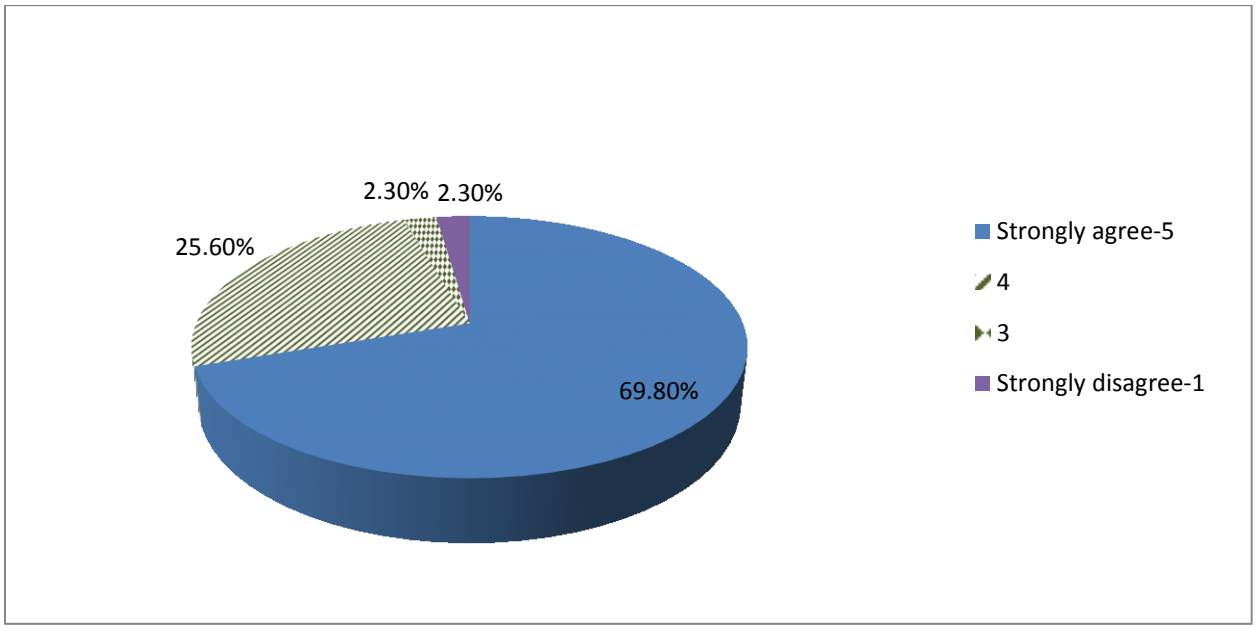


Figure 3: Performance measurement is important

Knowing that it is very important for most of the SCs both from our results and from the literature it was interesting to compare this with the results of the next question which asked the respondents whether they in fact do implement any performance measurement system.

- Have you implemented any kinds of performance measurement system(s) in the whole SC?

Based on the 43 responses, 33(76.7%) SCs have implemented performance measurement systems, 10(23.3%) SCs have not implemented any kind of performance measurement systems. Since most of SCs already use performance measurement systems and most of the respondents consider them very important. SC performance measurement has been studied since the time when the concept of SCM was founded. Many researchers have stated that the SC is complicated to measure because the SCM is a complicated concept and it has so many approaches and different meanings. According to (Gunasekaran A. P., 2001), there are two fundamental

challenges in measuring SCs. First, the lack of a balanced approach in integrating financial and non-financial measures. Second, the lack of system thinking, in which a SC must be viewed as a whole entity and the measurement system should span the entire SC (Sillanpää, 2010; Gunasekaran, 2001). Therefore, facing these issues, it is very important to implement performance measurement systems. Concerning the implemented performance measurement systems, the results are shown in **Figure 4**:

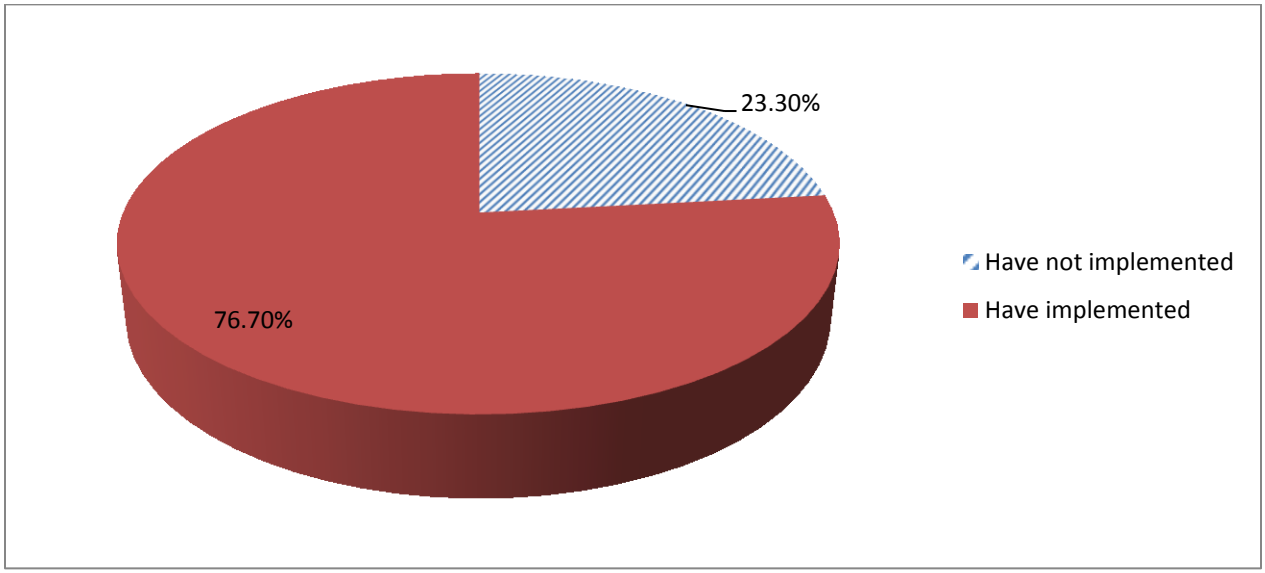


Figure 4: Implementation of performance measurement systems

- If 'Yes', please choose performance measurement system(s) which has (have) been implemented in the whole SC?

Based on the implemented performance measurement systems, I list the three systems' status as below:

BSC (20 supply chains)
SCOR (15 supply chains)
TQM (11 supply chains)

It is clear that BSC ranks as first, followed by SCOR, and finally by TQM. As we know, BSC is a very popular performance measurement system today, because it tries to measure both financial

and non-financial aspects of an entire SC. It was thus expected that BSC would rank in the first position compared to the other two performance measurement systems. As I mentioned earlier in this thesis, The SCOR model involves more than sixty process steps and more than two hundred metrics. While the Supply Chain Council indicates that the model can be used in almost every industry, and in any SC from a simple SC network to a very complex one, the SCOR model is in fact not really easy to implement. In order to use the SCOR model effectively, managers need to examine and understand their companies' specific SC processes. Simply following all the processes and metrics listed in the SCOR model will not work for most companies. First, the SCOR model was originally designed mainly for the manufacturing industry, and so a large portion of the model is focused on three processes, "Make" (production), "Build-to-Order Product Source" and "Deliver" (Chou, 2004). This may be one of the reasons that SCOR ranks in the second position among three performance measurement systems. TQM is a very general performance measurement system compared to BSC and SCOR, it is a very flexible system and different SCs can choose their preferred perspectives and attributes, therefore it is comparably not specific. The results are shown in **Figure 5**:

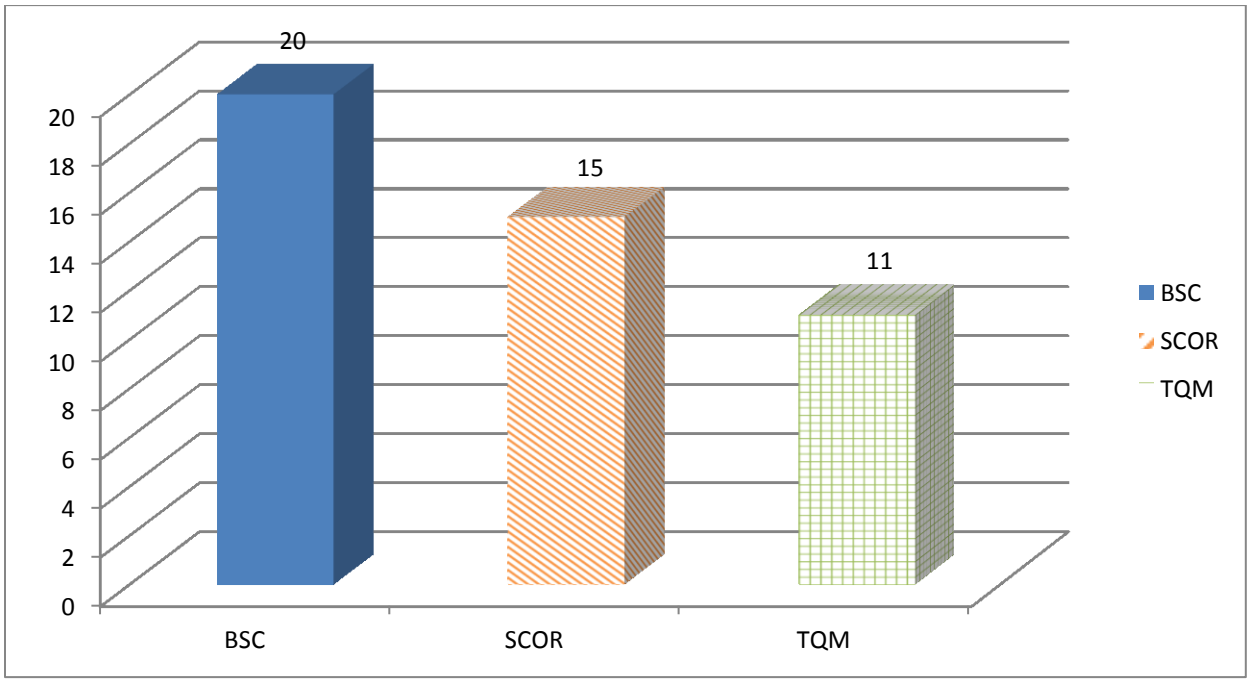


Figure 5: Number of supply chains

- What is (are) the main reason(s) which prevent(s) the whole SC from implementing performance measurement system(s)?

Based on the responses of the respondents whose SCs have not implemented any performance measurement systems, the reasons that respondents chose are listed below:

7 respondents chose “Time”
6 respondents chose “Manpower”
5 responses chose “Lack of management commitment”
4 respondents chose “Cost”
4 respondents chose “Lack of data”
2 respondents chose “Lack of priority among projects”
2 respondents chose “Lack of knowledge”

We can see that time and manpower is the most important reason which prevents SCs to implement performance measurement systems. Meanwhile, it is also surprising to see that “Cost” ranks not as high as expected.

In one of the key research papers which I have reviewed in the literature review part (Bourne, 2002), the difficulties related to the implementation of performance measurement systems in three companies are discussed. The author launched semi-structured interviews, discussing some of the problems the companies faced when designing and implementing the performance measurement systems, and, in particular, the difficulties they had overcome. Analysis of the semi-structured interview results revealed four main themes which were cited across all three case companies. These four themes (in order of citation) were (Bourne, 2002):

(1) Difficulties with data access and the information technology systems (coded as “IT’’)
(2) The time and effort required (coded as “effort’’)
(3) Difficulties concerned with developing appropriate measures (coded as “measuring’’)
(4) The personal consequences of performance measurement (coded as “consequences’’)

We can see that "Time" and "Lack of data" were mentioned among difficulties. And the "Lack of management commitment" was also mentioned in the unsuccessful company's part.

However, out of my expectation, "Manpower" ranks as the second reason which prevents implementing performance measurement systems in SCs. This reason was not even mentioned in the discussed article (Bourne, 2002). The importance of this factor can be explained by the fact that if the business is growing sometimes the manpower is tight and more time is needed to hire new employees. This may probably prove as critical for the parts of the business which are not existentially essential.

As fewer respondents chose "Lack of priority among projects" and "Lack of knowledge", we can conclude that these reasons exist, but they may not be as represent as critical factors as was expected for manufacturing SCs in terms of the implementation of performance measurement systems. The results are shown in **Figure 6**:

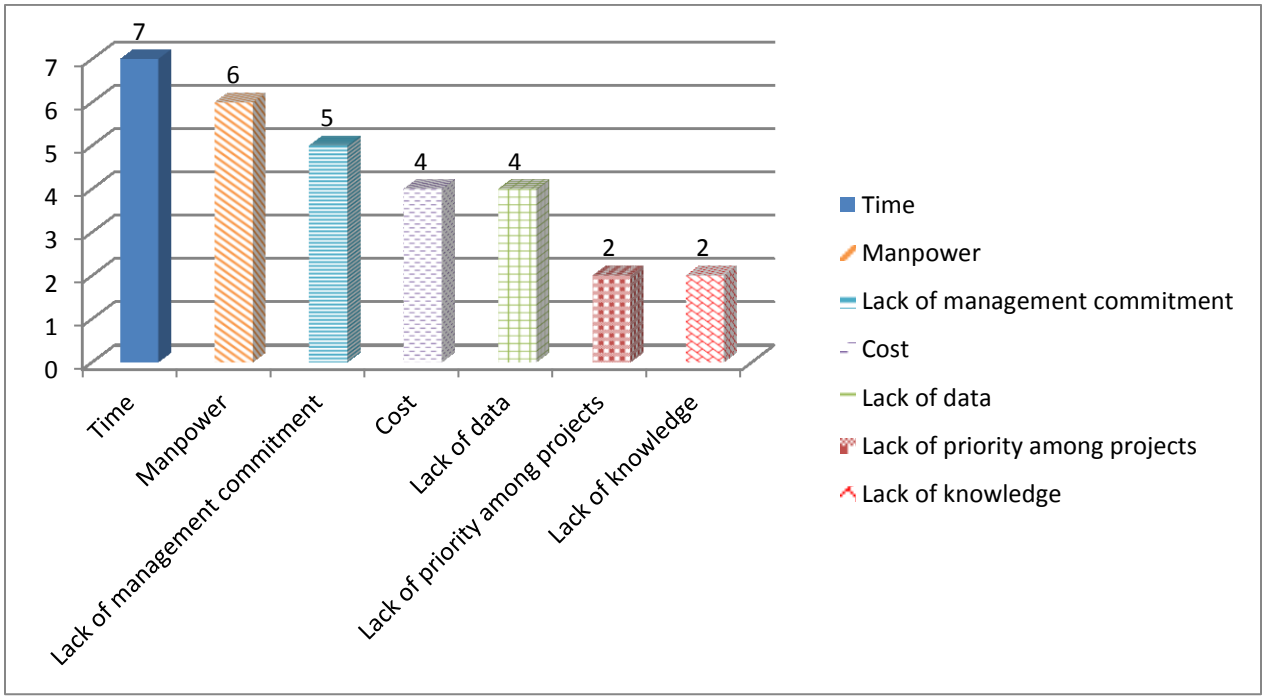


Figure 6: Reasons to prevent the whole SC from implementing performance measurement system

- Which aspect of the whole SC is the most important to measure?

Based on the 43 responses:

23(53.5%) respondents chose “reliability”
6(14 %) respondents chose “cost”
4(9.3%) respondents chose “time”
4(9.3%) respondents chose “flexibility”
6(14%) responses’ answers are not concerned because more than one option have been chosen

Out of my expectation, the importance of “reliability” scores higher than “cost” or “time”. It seems that professionals are very concerned by “reliability” of a manufacturing SC. The “reliability” is built up on trust and capability with business partners. Trust means you can have better cooperation with your partners and the flows in SCs could run smoothly. Capability means facing urgent issues, the entities in the SCs can have the ability to handle and resolve them in order to make the whole SC reliable.

Beamon (1999) mentioned that cost is the performance measure of choice for many SC models. Cost is very important to measure, and one of the reasons to develop BSC is to balance the measurement of cost and non-cost perspectives. Therefore, it is common to see that a few respondents chose “cost” as the most important aspect to measure among their SCs.

“Time” is expectedly vital for the companies. “On-time delivery”, “Backorder” and “Customer response time” are all important time-related factors. Together with "flexibility" it is also included in Beamon’s new framework for SC performance measurement (Beamon, 1999). The results are shown in **Figure 7**:

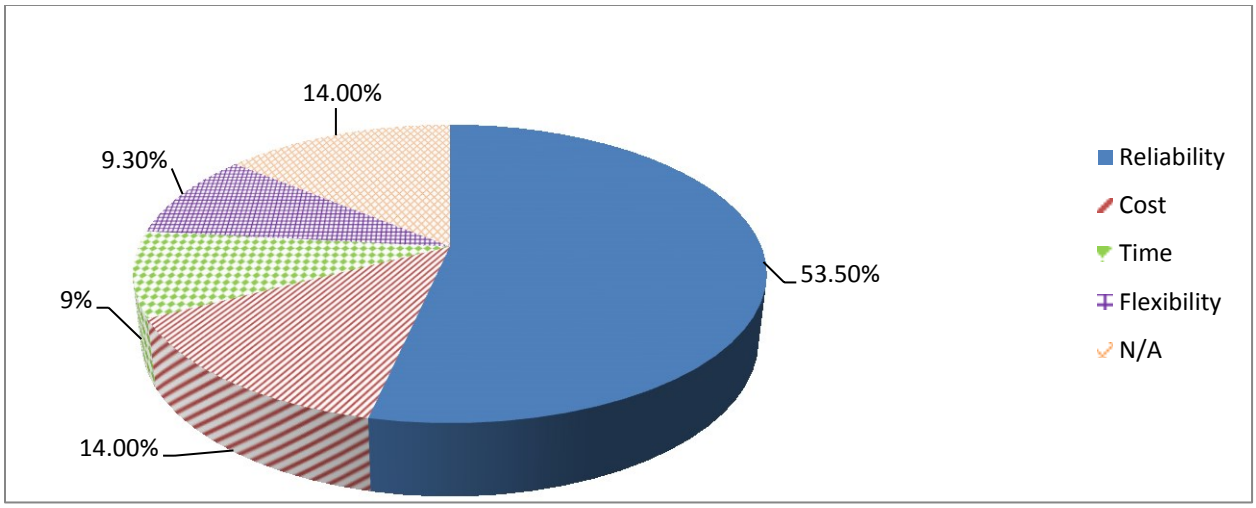


Figure 7: The most important aspect to measure

5.2 Analysis of data from part 3 and part 4 of questionnaire

I intended to get the mean of importance weight and mean of performance for each attribute. Because populations of SC are unknown, as are the variances of the populations I intend to calculate the mean of the population which are all responses against individual attribute, therefore I applied sample distribution with student T distribution:

$$t_0 = \frac{\bar{x}-\mu_0}{s/\sqrt{n}}$$

I wish to test the hypothesis of population mean of each attribute using α = 0.05, two tails of t: $t_{0.025,n-1}$, - $t_{0.025,n-1}$, therefore if the calculated value of the test statistic does not exceed value of $t_{0.025,n-1}$ or - $t_{0.025,n-1}$, I cannot reject the null hypothesis which is the mean of all responses' values. Therefore, there is no strong evidence to conclude that the mean of the population of responses is different from the hypothesis. The values of means in the rest of paper are all hypotheses which have been verified.

In this second data analysis part, I will discuss in two aspects, the first one will be from four perspectives which are resource, customer-based interaction, SC-based interaction and flexibility, I will present the results by applying 4 indexes. The second aspect will be from 23 attributes

which are listed in the questionnaire. I will apply different statistical analysis methods to discuss them in details.

5.2.1 Data analysis of perspectives

As already described previously, I have defined 4 perspectives in part 3 and part 4 of questionnaire as the main categories of SC performance measurement. These are resource, customer-based interaction, SC-based interaction and flexibility. In the initial part of data analysis I will focus on these 4 perspectives, however a separate analysis for each of the 23 attributes would not allow me to create a comprehensive picture. The integration of these attributes into one comprehensive evaluation indicator is thus necessary. In order to combine the attributes covered by each perspective while considering the importance of each attribute a new index was developed. I call the index "**Supply Chain Performance Index (SCP Index)**". The SCP Index is composed of 4 indexes, each representing the total value of weighted performances of all the attributes within each perspective. The mathematical expression for the calculation of each of the 4 indexes is as follows:

$$Z = \left(\frac{x_1}{\sum_n^1 x} \times y_1\right) + \left(\frac{x_2}{\sum_n^1 x} \times y_2\right) + \ldots + \left(\frac{x_n}{\sum_n^1 x} \times y_n\right)$$

x: value of importance

y: value of status

n: number of attributes

Z: weighted performance

Each of the indexes will thus give us the weighted performance for each of the perspectives (resource, customer-based interaction, SC-based interaction and flexibility). The set of these 4 indexes represents the total SCP index calculated for each SC. The SCP Index thereby allows comparisons of the SCs and their performance measures based on various factors. I will discuss these in the following 4 sections, which are focused on the comparisons based on industry, country, the presence of strategic alliance and performance measurement systems.

5.2.1.1 Data analysis of perspectives based on Industry

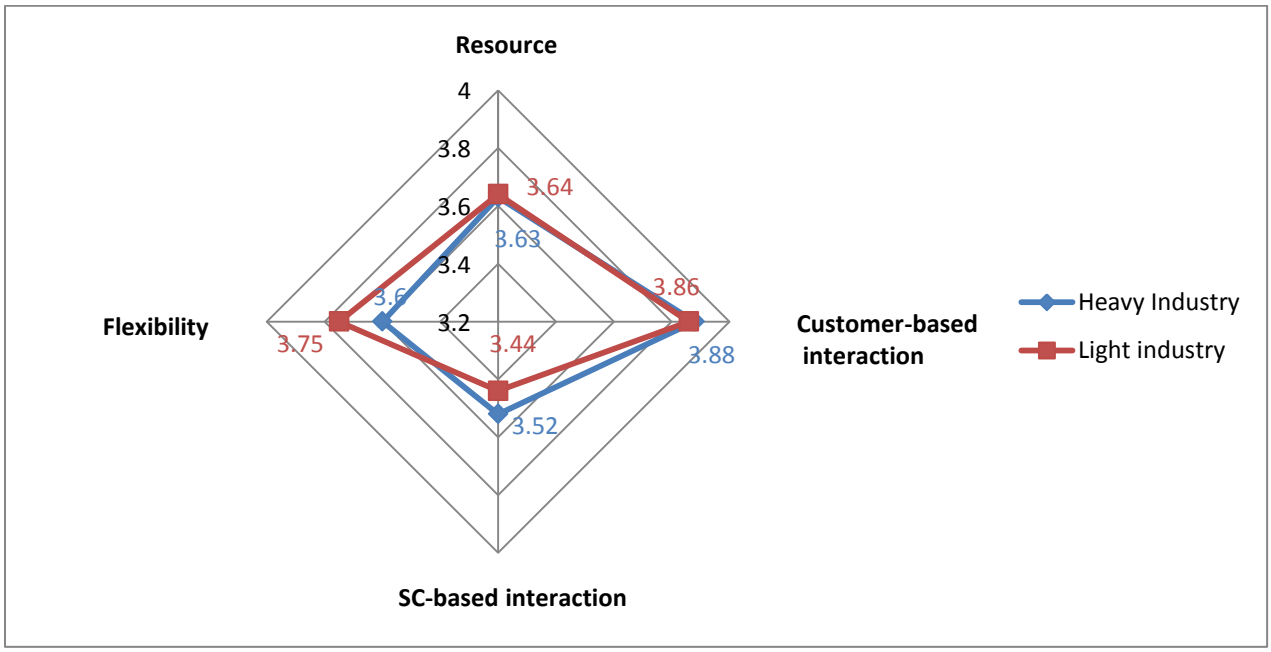


Figure 8: SCP Index comparing SCs in light and heavy industries

From **Figure 8**, we can clearly see that 4 weighted performance indexes from light industry and heavy industry. It is remarkable to see that the indexes of flexibility and SC-based interaction have quite large gaps between light industry and heavy industry. One of the reasons may be related to end-users. Light industry SC is dealing with end-users and their SCs have to be more flexible to fulfill various types of end-user's requirements. Meanwhile, it is easier for heavy industry SCs to cooperate with other entities in their SCs, so the performance of SC-based interaction is better from heavy industry SCs.

It is very interesting to see this figure and get to know the weighted performance of light industry and heavy industry SCs. This result will play as a role of reminder to both light and heavy industry to put more attention on their SC's performance.

5.2.1.2 Data analysis of perspectives based on country

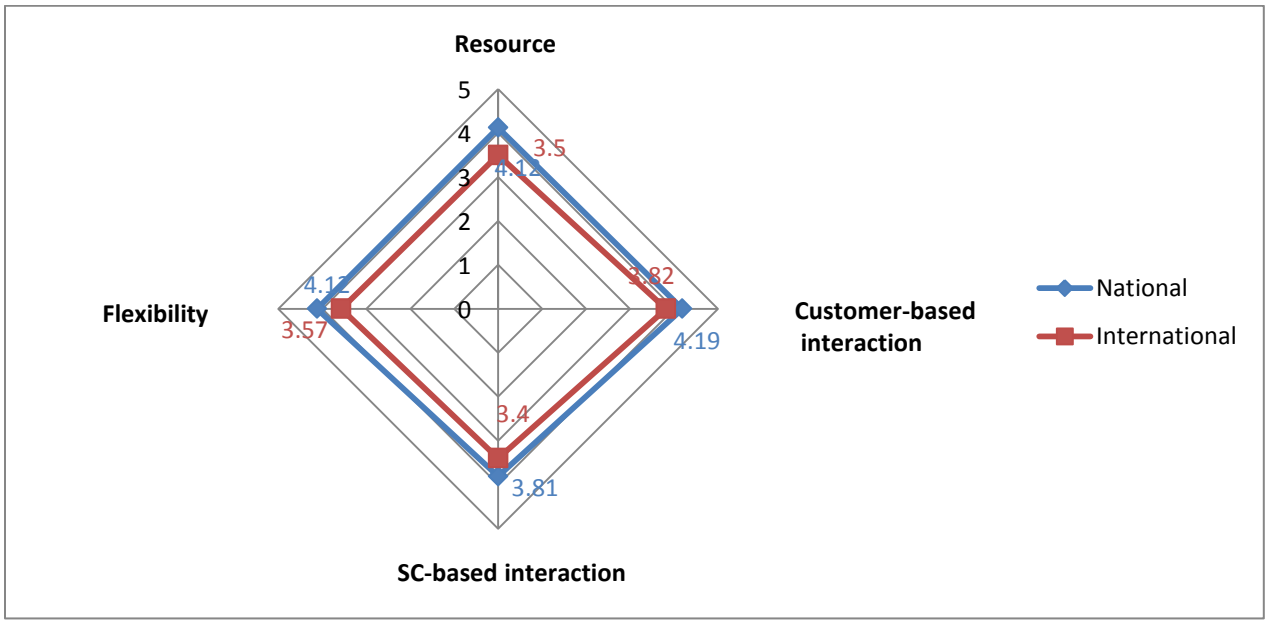


Figure 9: SCP Index comparing SCs in national and international industries

From **Figure 9**, we can compare the SCP Index for the SCs existing national and international SCs. It is interesting that we can easily see that all weighted performances from SCs within country are better than them from international SCs. One of the reasons may be related to the long distance interactions and business culture shocks, international SCs are involved in more complicated situations and it is more difficult to perform well.

5.2.1.3 Data analysis of perspectives based on strategic alliance

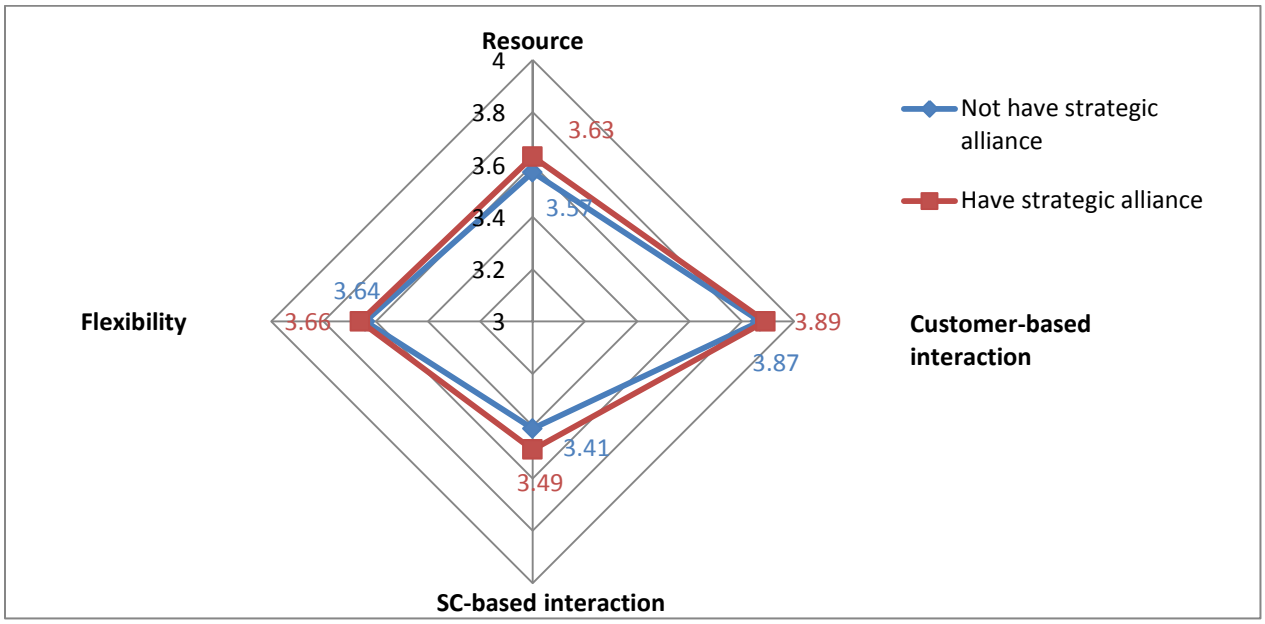


Figure 10: SCP Index comparing SCs with and without strategic alliance

Next, I investigated the difference in the performance of SCs which have and do not have strategic alliance. All perspectives of SCs which have strategic alliance have greater values of weighted performance indexes than the SCs which do not have strategic alliance. The reason is that when entities are in a same alliance, they can share their information, goals and strategies. The cooperation and workflow should be better and the performance of the whole SC is thus expectedly enhanced.

Strategic alliance is a new concept which has been applied more and more in the current business world. The power of strategic alliances should be considered seriously as it can improve the performance of manufacturing SC.

5.2.1.4 Data analysis of perspectives based on performance measurement systems

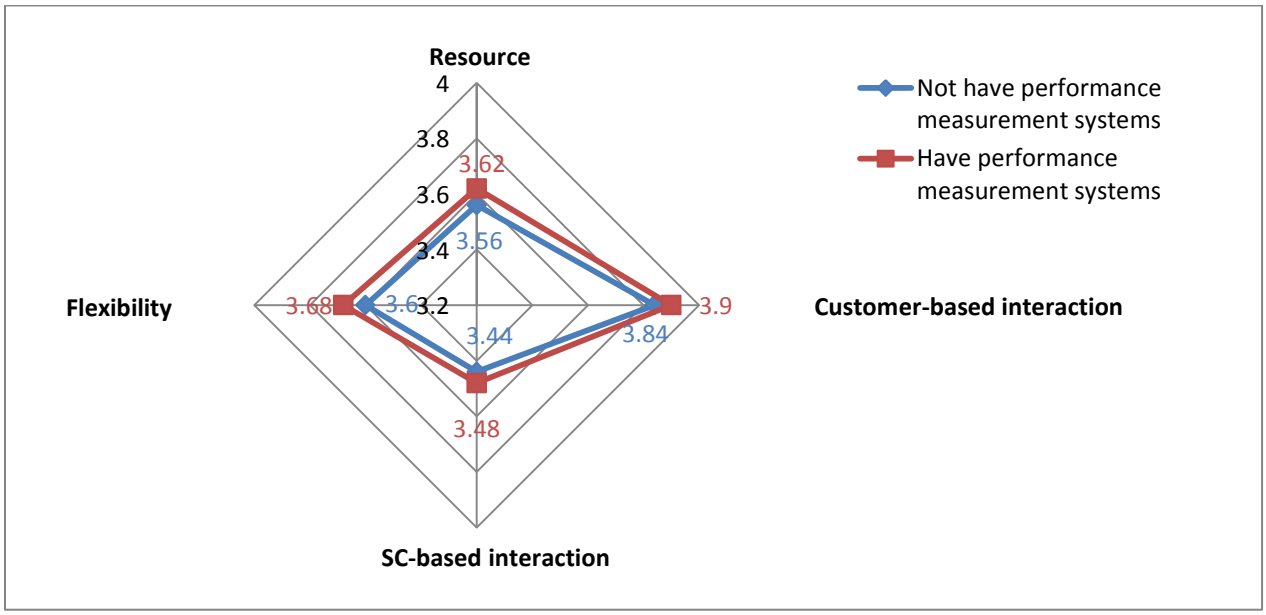


Figure 11: SCP Index comparing SCs with and without Performance Measurement Systems

Figure 11 compares the SCP Indexes for SCs which use performance measurement systems with the ones which do not. From the figure it is clear that all the SCs which have performance measurement systems perform better than SCs which do not have performance measurement systems. This was expected, because the entities within SCs with performance measurement systems are able to evaluate the functioning of their SCs and thus it is much easier for them to find the problematic issues and resolve them compared to SCs which do not have performance measurement systems. Such SCs will continuously work towards the improvement in their operations and then they will likely achieve higher SC performance levels.

To summarize the results from this section, four conclusions can be made. Depending on the weighted performances from 4 different perspectives, first, light industry SCs perform better than heavy industry SCs from flexibility perspective and heavy industry SCs perform better than light industry SCs from SC-based interaction perspective. Second, national SCs show better performance than international SCs. Third, SCs which have strategic alliance perform better than SCs which do not have strategic alliance. Fourth, SCs which have performance measurement systems perform better than SCs which do not have performance measurement systems.

5.2.3 Data analysis of attributes

In this section some selected attributes are presented and the results in terms of their importance and performance in various manufacturing SCs are discussed and compared. Evaluations and comparisons were performed based on different industries, different countries, based on the adherence of the companies to a strategic alliance and based on the use of the performance measurement systems in the companies. The findings based on these four factors are going to be discussed in the following four sections. Since the data was collected for all 23 attributes, only some will be selected and presented here. Each section will first discuss the attributes which have obtained the highest value of importance for each of the compared groups, and afterwards I will focus on the gap in the attribute importance between the groups and then on the gap in their performance. Finally, I will summarize the most important attributes in each of these categories to best characterize each of the compared groups.

5.2.3.1 Data analysis of attributes based on Industry

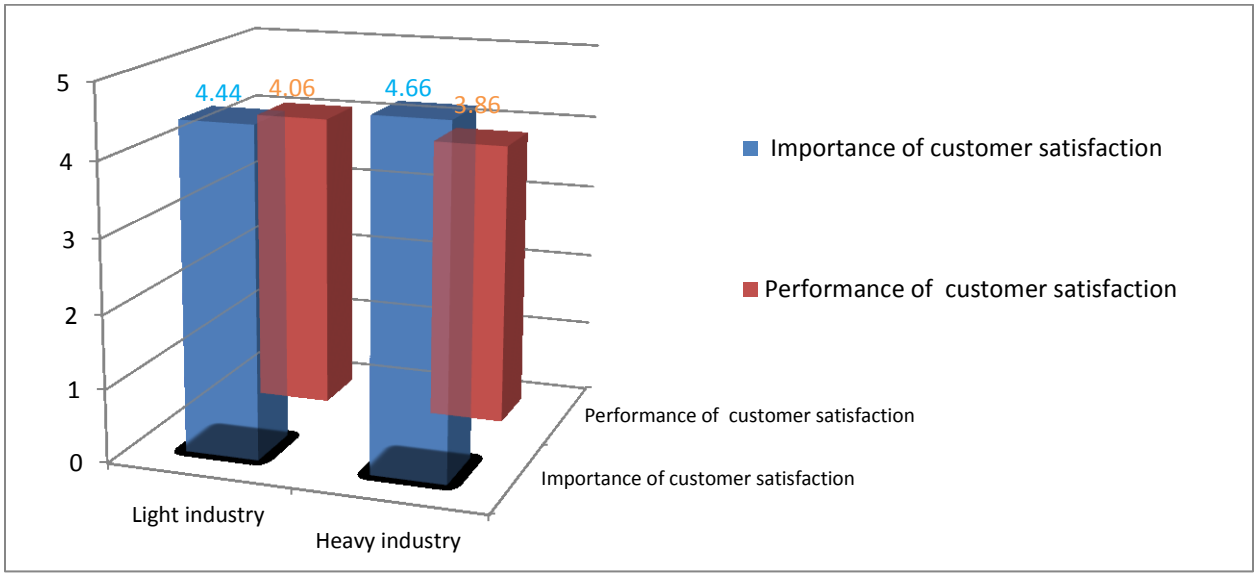


Figure 12: Attribute with highest value of importance in heavy industry compared to light industry

From **Figure 12** we can see that although customer satisfaction in heavy industry is more important than it is in light industry, the performance of this attribute in heavy industry is worse than it is in light industry. One of the reasons for the high importance of customer satisfaction in heavy industry may be again related to the nature of the heavy industry customers. These are usually smaller groups such as large companies, business groups, or governments, where each customer may represents a great part of the business. Their best possible satisfaction for the customers is thus required, because if the customers are not satisfied, the companies may lose a great part of their business. In light industries, on the other hand, the customers are numerous and have more choices and targets compared to heavy industry. Obviously, customer satisfaction still plays an important role for them, but it is interesting to find here that in heavy industries the customer satisfaction is in fact perceived as more significant than in light industries. In terms of the performance, the results show that it is in light industries where the customer satisfaction is actually better achieved than in heavy industry. This gives us an interesting and realistic picture of the customer satisfaction in the supply chain in both industries.

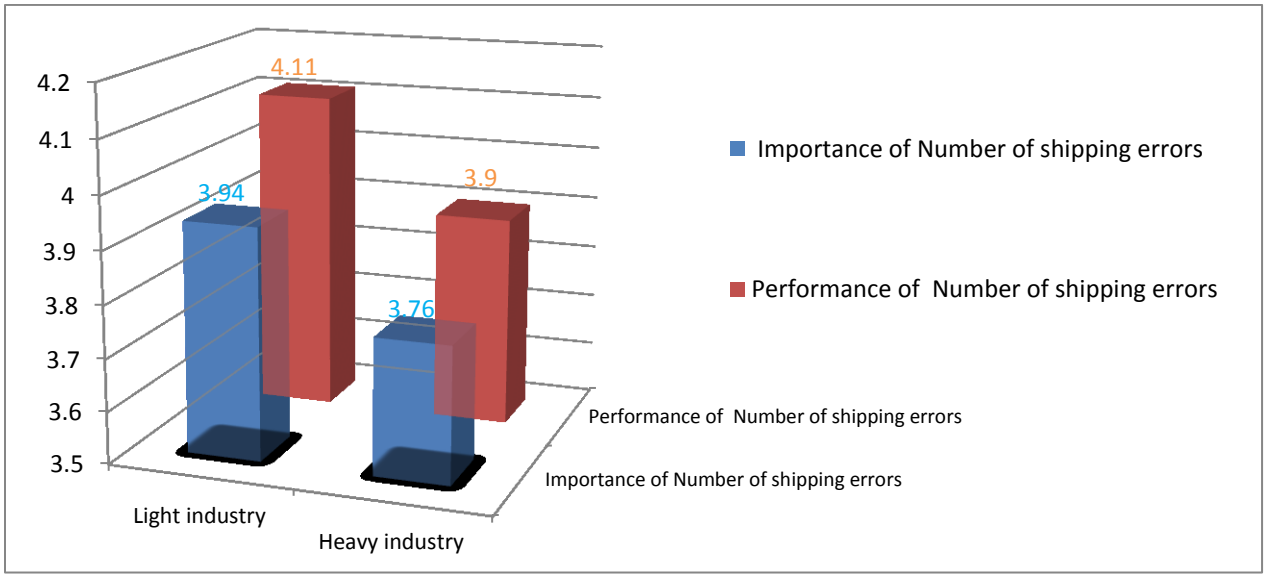


Figure 13: Attribute with highest value of performance in light industry compared to heavy industry

In **Figure 13** we can observe the value for performance of number of shipping errors is the highest of all the light industry SC values. One of reasons may be related to personal carriers who are taking charge of delivery of light industry products, they are more reliable and they can

deliver accurately. However, heavy industry SCs cannot use personal carriers because their products are very large.

Similar analysis has been carried out for the rest of the 23 attributes. Only some exemplary findings with the top values obtained were discussed above, but there were other attributes which had high values of importance for light and heavy industries and gaps in the performances between the two industry types. **Table 15** summarizes these results. Based on that I can conclude that there is no great difference between supply chain performance in heavy and light industries.

Table 15: Most important attributes for light and heavy industries with their importance and performance values

Light Industry		
Attribute	**Importance**	**Performance**
Customer satisfaction	4.44	4.06
Number of successful on time deliveries	4.44	4
Minimization of cost	4.39	3.72
Efficient utilization of resources	4.39	3.61

Heavy Industry		
Attribute	**Importance**	**Performance**
Customer satisfaction	4.66	3.86
Number of successful on time deliveries	4.45	4.03
Minimization of cost	4.38	3.72
Fulfill rate	4.38	4.17

This analysis provided us with an interesting picture of the SC performance values for light and heavy industries. This was only a glimpse into the issue, but it is certainly an interesting research direction which can be explored in future. Within the research papers which I have reviewed I found that many of them were related to the performance measurement in manufacturing SCs, but, to my knowledge, no work has provided an in depth analysis of the possibly different SC performance in light and heavy industries.

5.2.3.2 Data analysis of attributes based on country

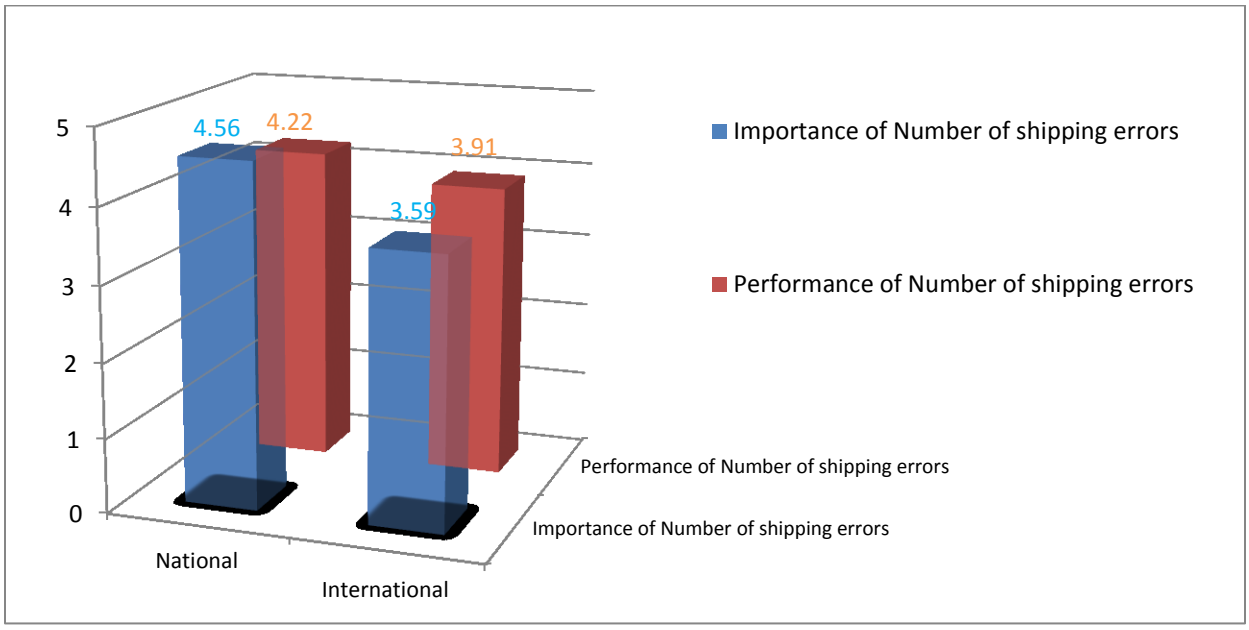


Figure 14: Attribute with highest value of importance in national SCs compared to international SCs

In this section the findings are presented and compared based on two groups - national SCs and international SCs. As **Figure 14** shows the highest value of importance of an attribute within national SCs was obtained by the number of shipping errors. Concerning the performance, the deliveries within international SCs are more complex compared to national SCs. Delivering products in the international environment entails various transportation means and more complicated logistics arrangements, various international fees and taxes, duties at the borders, etc. Even though they have built a very strong capability of delivery; it is difficult for them to perform better because of these complexities.

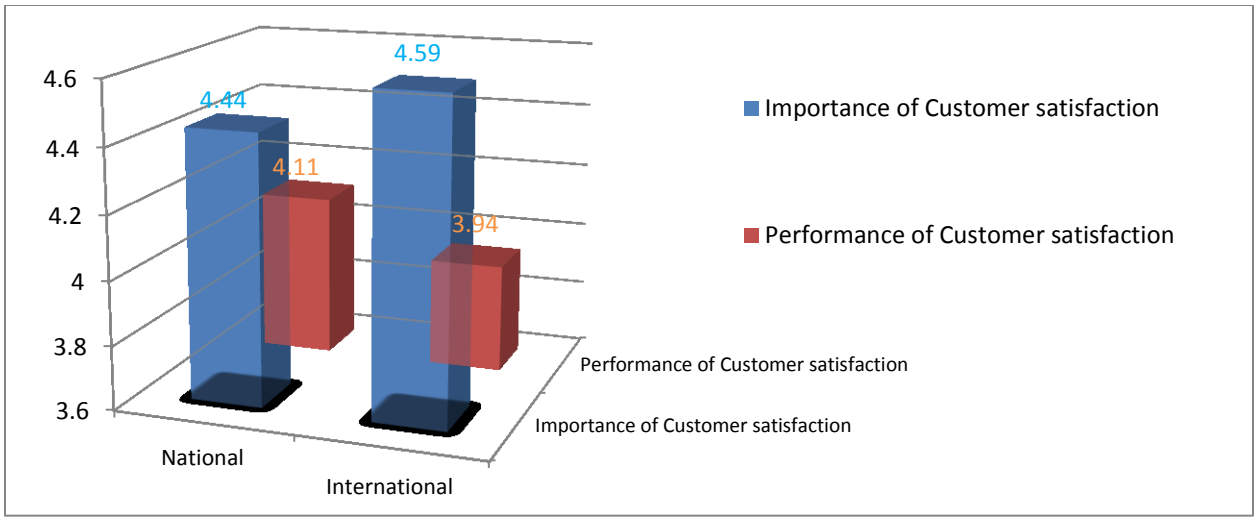


Figure 15: Attribute with highest value of importance in international SCs compared to national SCs

For international SCs, it is the value of importance of customer satisfaction which scored the highest. Due to the fierce global competition the customer satisfaction in international SCs is understandably quite critical. It is more difficult for the companies within international SCs to build up their business, and it is even more difficult to sustain their competitive advantage. The possible loss of their customers due to the cultural or other environmental differences is a pervasive threat in the international SCs. The companies in national SCs on the other hand co-exist within the same environment and culture, they are regulated by the same government and they are more familiar with each other. Therefore, they may feel more comfortable and confident to deal with their local customers. Concerning the performance, because of the cultural differences and different business standards, it is more difficult for international SCs to satisfy their customers compared to national SCs.

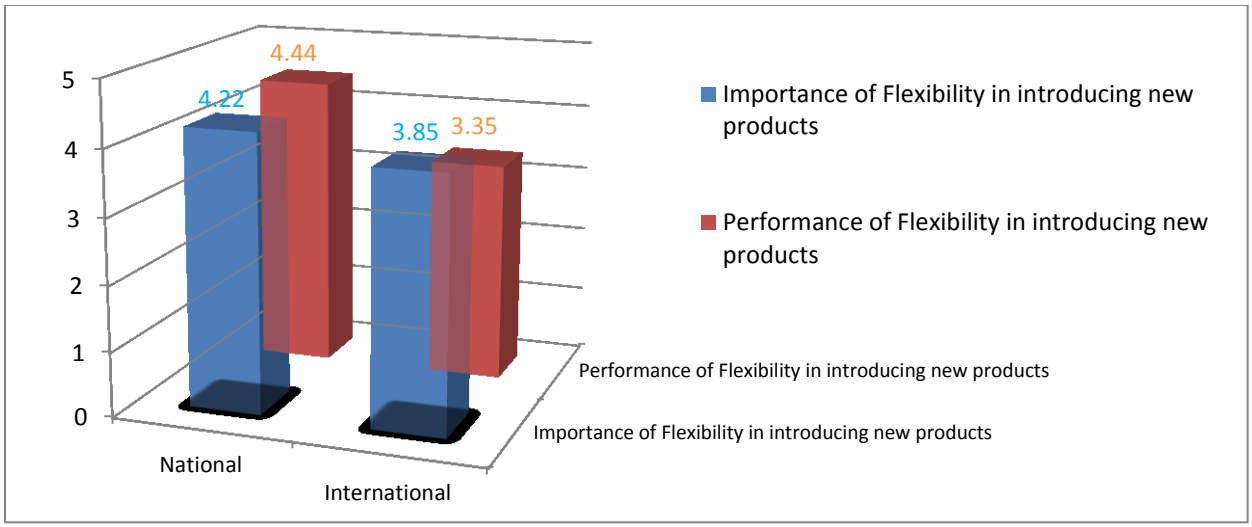


Figure 16: Attribute with largest gap of performance between national and international SCs

The largest gap of performance between national SCs and international SCs has been observed in the attribute of flexibility in introducing new products. As discussed previously, the organizations within local SCs are more familiar with each other and with each other's business environment, and they can know customer's requirements more easily. Since information sharing among companies is more challenging in international SCs and it is difficult for them to know their remote customers' demands, hence the lower value on the performance of this attribute for the international SCs.

Table 16: Most important attributes for national and international SCs with their importance and performance values

National SCs		
Attribute	**Importance**	**Performance**
Number of shipping errors	4.56	4.22
Customer satisfaction	4.44	4.11
Minimization of cost	4.44	4.22

International SCs		
Attribute	**Importance**	**Performance**
Customer satisfaction	4.59	3.94
Number of successful on time deliveries	4.44	3.94
Fulfill rate	4.38	4.09
Minimization of cost	4.29	3.59

Table 16 summarizes these results. In international SCs, a great emphasis is placed on customer satisfaction, which is the highest scoring attribute, and on other much related attributes such as number of successful on time deliveries, minimization of cost and fulfill rate. Global competition in international SCs is fierce, which forces the companies to consider satisfying their customers as the most important and critical element of their business. National SCs have the similar trend as international ones.

5.2.3.3 Data analysis of attributes based on strategic alliance

Table 17: Most important attributes for SCs which have and do not have strategic alliance with their importance and performance values

SCs without strategic alliance		
Attribute	**Importance**	**Performance**
Customer satisfaction	4.54	3.95
Number of successful on time deliveries	4.43	3.98
Fulfill rate	4.32	4.08
Minimization of cost	4.30	3.65

SCs with strategic alliance		
Attribute	**Importance**	**Performance**
Customer satisfaction	4.55	3.98
Number of successful on time deliveries	4.45	4
Fulfill rate	4.36	4.10
Minimization of cost	4.33	3.69

Table 17 summarizes the results. In general, we can see that the most important attributes from SCs which do not have strategic alliance and SCs which have strategic alliance are exactly same. However, we can see that although the values of importance are similar to each other, the values of performance of SCs which have strategic alliance are greater than those which do not have strategic alliance. The reason is likely related to the benefits of being in a strategic alliance discussed previously.

5.2.3.4 Data analysis of attributes based on performance measurement systems

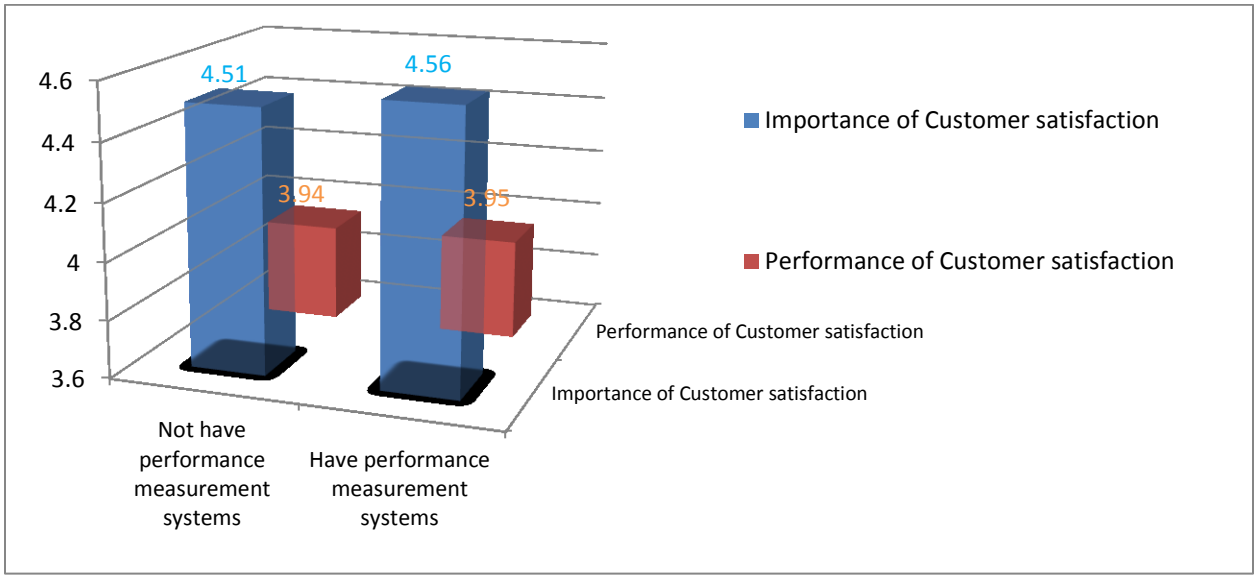


Figure 17: Attribute with highest value of importance in SCs with Performance Measurement Systems

The highest scoring attribute in terms of its importance for the companies which have performance measurement systems of their SCs is the level of customer satisfaction. The results presented in **Figure 17** show that customer satisfaction in SCs which have performance measurement systems is more important than it is in SCs which do not have performance measurement systems. Also, these companies score with higher performance of this attribute. It may be assumed that the companies which are regularly measuring performance of their SCs most likely also give a high priority to customer satisfaction, which is perceived as critically important for their business. The SCs which do not measure the SC performance may not be able to realize this, because they even do not have the data to analyze.

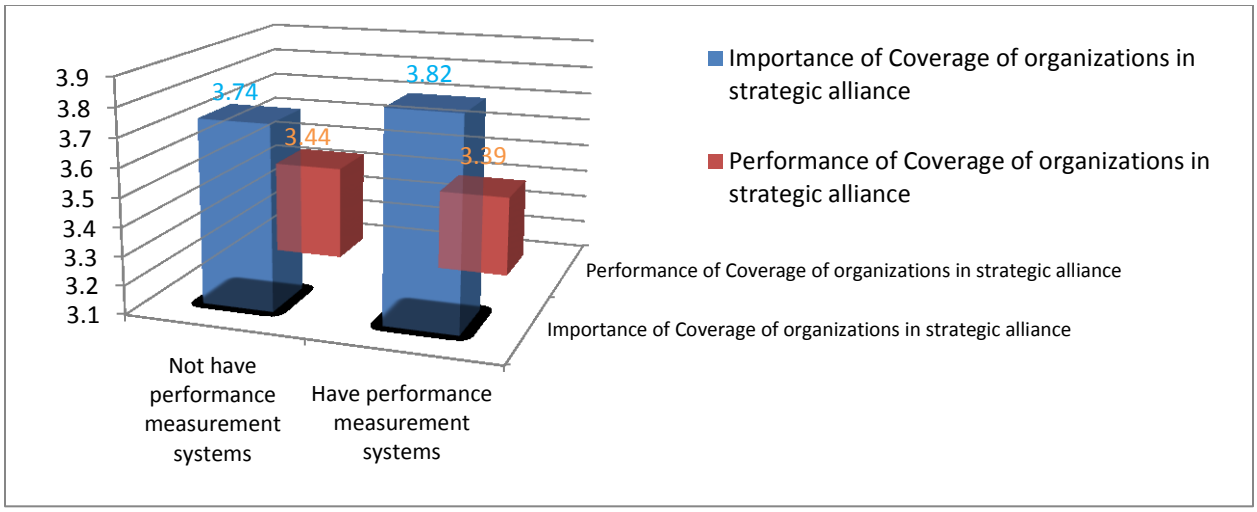


Figure 18: Attribute with largest gap of importance between SCs with and without Performance Measurement Systems

The largest gap of values of importance between SCs which have and do not have performance measurement systems is from attribute of coverage of organizations in strategic alliance. In the section above I suggest that the SCs which have performance measurement systems can evaluate the status of their SCs very well because of the performance measurement systems. This allows them to realize the high importance of being in a strategic alliance. However, the SCs which do not have performance measurement systems may not be able to recognize it and to act on it. Meanwhile, as the figure shows, the difference in the performance is not that great.

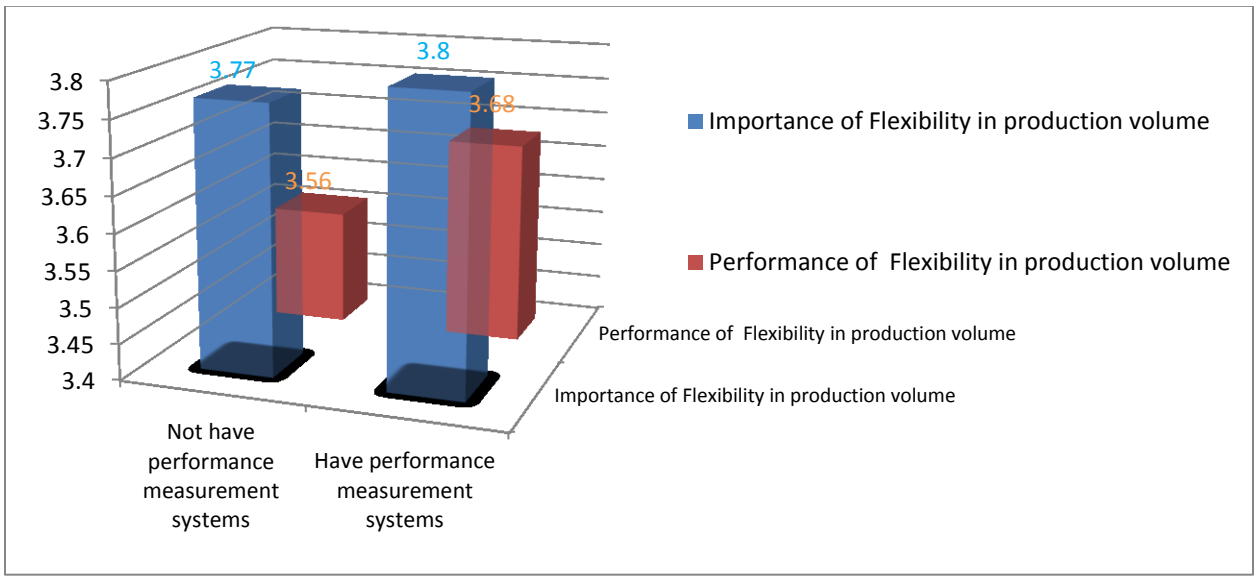


Figure 19: Attribute with largest gap of performance between SCs with and without Performance Measurement Systems

The largest gap of values of performance between SCs with and without performance measurement systems has been found for the attribute of flexibility in production volume. As **Figure 19** shows, the importance value follows a similar trend. One of the main reasons is related to performance measurement systems, companies in the SCs which have performance measurement systems can recognize the status of raw material, manpower, and budget well. It should be very easy for them to manage the production when they encounter some emergencies such as huge demands from their customers. However, the SCs which do not have performance measurement systems cannot notice this point and it is very hard for them to manage their resources and they are not well prepared when huge demand is coming.

Table 18: Most important attributes for SCs which have and do not have PMS in place with their importance and performance values

SCs without PMS		
Attribute	**Importance**	**Performance**
Customer satisfaction	4.51	3.94
Number of successful on time deliveries	4.44	3.95

SCs with PMS		
Attribute	**Importance**	**Performance**
Customer satisfaction	4.56	3.95
Number of successful on time deliveries	4.44	3.98
Fulfill rate	4.37	4.10

Table 18 summarizes the results of this section. We can see that customer satisfaction and number of successful on time deliveries are the most important attributes for SCs which do not have PMS and also SCs which have PMS. Because of the awareness of operation data, even the importance level of these attributes are similar to SCs with and without PMS, SCs which have PMS perform better than SCs which do not have PMS.

6. Summary and conclusions

In this thesis I have developed a tool for measuring performance of manufacturing SC. Even though there are some techniques and methods already existing, there are several factors which make this tool stand out. First, the tool is very simple and practical, and thus can be easily used for the performance measurement in manufacturing SC of any size. Second, the tool is generic, which makes it possible to be used by any company in any industrial manufacturing sector. Third, the developed tool involves weights given to the attributes, which makes the performance evaluation more accurate. I sincerely hope that the tools will be adopted in the real life manufacturing SCs.

In the second part of the thesis I have used the tool as a questionnaire in order to evaluate manufacturing SC performance and carry out a comparative analysis of existing SCs**.** First, I analyzed the general status of performance measurement of manufacturing SCs based on the globally collected data from various SCs in various countries and industries. There are several findings which I would like to highlight:

- Many manufacturing SCs still do not have any strategic alliance
- Performance measurement in the whole SC is considered by many to be very important
- Many SCs have not implemented any kind of performance measurement systems; the reason is mainly because of time, manpower and lack of management commitment
- The most commonly implemented performance measurement systems are BSC,SCOR and TQM
- Cost and reliability are the most important aspects which need to be measured
- The different perspectives and attributes' performance can be measured at a high level by applying the tool developed in this thesis

Second, I developed an index for the assessment of the SC performance and used it to evaluate weighted performances of manufacturing SCs based on 4 factors: Evaluations and comparisons were performed based on different industries, different countries, based on the adherence of the companies to a strategic alliance and based on the use of the performance measurement systems

in the companies. The findings show that all weighted performances from national SCs are better than those from international SCs. Moreover, I observed that all perspectives of SCs which have strategic alliance have greater values of weighted performance indexes than the SCs which do not have strategic alliance. Finally, SCs which have performance measurement systems perform better than SCs which do have the performance measurement systems.

Finally, I have focused on the individual attributes and highlighted the ones which obtained the highest importance values. Based on this analysis I conclude that there is a small difference between supply chain performance in heavy and light industries. In both SCs, a great emphasis is placed on customer satisfaction, which is the highest scoring attribute, and on other much related attributes such as number of successful on time deliveries and minimization of cost.

In SCs which have strategic alliance, I found that a great emphasis is given to attributes which are customer oriented, emphasizing thereby the need to keep the good relationships within the alliance.

For the SCs which have managed to build their own performance measurement systems it is customer satisfaction, the number of successful on time deliveries and fulfill rate which became the most important attributes.

7. Contributions

The main value of this work stems from several points discussed below:

- This thesis focuses on the whole manufacturing SC concept. There are only a few research studies which address the whole manufacturing SC, because most of the research is only focused on single company's supply chain

- There are only a few related research works which carry out research in different countries and different industries. Most of the research focuses only on one specific country or one

specific industry. Another uniqueness of this work is thus that it manages to cover the global scope from a variety of countries and industries

- I consider this work as a pioneer research which developed a methodology and a tool while using a general approach which enables the investigation of all types of manufacturing SC performance

- A 6 months survey was undertaken which allowed a collection of much valuable information concerning manufacturing SCs from different companies, industries, countries. The analysis based on the responses provided some characterization of several aspects of various supply chain and highlighted some improvements that can be done in order to optimize SC performance based on different perspectives and attributes

- The work is tightly connected with industries. A summary report will be created and sent to the interested participant in order to get them informed about the importance of performance measurement of manufacturing SC

8. Limitations

There are also some limitations for this research:

- we cannot gain the raw data concerning SCs to do further research based on detailed level

- Attributes for particular manufacturing SCs are not discussed

- Because of the duration of this research, we cannot see the efficiencies and effectives of this tool to help industries to improve their performance measurement capability on their SCM

- The methodology and tool which have been developed are not integrated with current real applications of performance measurement systems, e.g. SAP SCPM and PeopleSoft Enterprise SCM

9. Future works

Some future works will be according to the limitations of this research:

- Future research can be undertaken at a more detailed level to performance measurement systems of manufacturing SCs with cooperation with companies

- The methodology and tool could be implemented on industries and investigated consistently

- Attributes for particular manufacturing SCs could be developed

- The tool which has been developed could be integrated with IT application implementations in industries such as SAP SCPM and PeopleSoft Enterprise SC

Bibliography

Adrien Chia, M. G.-H. (1999). Performance measurement in supply chain entities: balanced scorecard perspective. *Benchmarking: An International Journal*, 605-620.

Ambuj Khare, A. S. (2012). Supply Chain Performance Measures for gaining Competitive Advantage: A Review. *Journal of Management and Strategy*, Vol. 3, No. 2, p25-32.

Barbara Bigliardi, E. B. (2010). Performance measurement in the food supply chain: a balanced scorecard approach. *Facilities*, Vol. 28 Iss: 5 pp. 249 - 260.

Basnet, C. C. (2003). Benchmarking supply chain management practice in New Zealand. *Supply Chain Management: An International Journal*, Vol. 8 No. 1, pp. 57-64.

Beamon, B. (1996). Performance measures in supply chain management. New York: Rensselaer Polytechnic Institute

Beamon, B. (1998). Supply chain design and analysis: models and methods. *International Journal of Production Economics*, Vol. 55, pp. 281-94.

Beamon, B. (1999). Measuring supply chain performance. *International Journal of Operations and Production Management*, Vol. 19 Nos 3-4, pp. 275-92.

Beamon, B. a. (2001). Performance analysis of conjoined supply chains. *International Journal of Production Research*, Vol. 39 No. 14, pp. 3195-218.

Benton, W. a. (2005). The influence of power driven buyer/seller relationships on supply chain satisfaction. *Journal of Operations Management*, Vol. 23, No. 1, pp. 1–22.

Besterfield-Sacre. (2003). *Total Quality Management.* Upper Saddle River: NJ: Person Education,Inc

Bierbusse, P. a. (1997). Measures that matter. *Journal of Strategic Performance Measurement*, Vol. 1 No. 2, pp. 6-11.

Bititci, U. C. (2005). Implementation of performance measurement systems: private and public sectors. *Production Planning and Control*, Vol. 16, No. 2, pp. 99-100.

Bourne, M. M. (1999). Performance measurement system design: testing a process approach in manufacturing companies. *International Journal of Business Performance Measurement*, Vol. 1 No. 2, pp. 154-70.

Bourne, M. M. (2000). Designing, implementing and updating performance measurement systems. *International Journal of Operations and Production Management*, Vol. 20 No. 7, pp. 754-71.

Bourne, M. N. (2002). The success and failure of performance measurement initiatives: perceptions of participating managers. *International Journal of Operations and Production Management*, Vol. 22 No. 11, pp. 1288-310.

Boyer, K. a. (2002). Competitive priorities: investigating the need for trade-offs in operations strategy. *Journal of Operations Management*, Vol. 11, No. 1, pp. 9–20.

Brewer, P. S. (2000). Using the balanced scorecard to measure supply chain performance. *Journal of Business Logistics*, Vol. 21, No. 1, pp. 75–94.

BS4778, B. S. (1987). Quality Vocabulary. London

Camp, R. (1989). *Benchmarking ± The Search for Industry Best Practices that Lead to Superior Performance.* Milwaukee: ASQS Quality Press

Caprice, C. S. (1994). A review and evaluation of logistics metrics. *International Journal of Logistics Management*, Vol. 5, No. 2, pp. 11–28.

Caprice, C. S. (1995). A review and evaluation of logistics performance measurement systems. *International Journal of Logistics Management*, Vol. 6, No.1, pp. 61–74.

Chan, F. (2003). Performance measurement in a supply chain. *International Journal of Advanced Manufacturing Technology*, Vol. 21, pp. 534-48.

Chan, F. T. (2003). An innovative performance measurement method for supply chain management. *Supply Chain Management: An International Journal*, 8(3–4), 209–223.

Chen, I. a. (2004). Understanding supply chain management: critical research and a theoretical framework. *International Journal of Production Research*, Vol. 42 No. 1, pp. 131-63.

Chen, S. J. (2007). A systematic approach for supply chain improvement using design structure matrix. *Journal of Intelligent Manufacturing*, 18, 285–299.

Chou, C.-F. (2004). *Development of a Comprehensive Supply Chain Performance Measurement System: A Case Stduty in the Grocery Retail Industry.* MIT

Christopher. (2000). The Agile Supply Chain: Competing in Volatile Markets. *Industrial Marketing Management*, 29(1): 37–44.

Christopher, M. a. (2001). An integrated model for the design of agile supply chains. *International Journal of Physical Distribution and Logistic Management*, Vol. 31, pp. 235–246.

Clegg, C. W. (2002). An international survey of the use and effectiveness of modern manufacturing practices. In *Human Factors & Ergonomics in Manufacturing* pp. 12, 171–191.

Cooper, R. a. (1988). Measure costs right: make the right decisions. *Harvard Business Review*, Vol. 66 No. 5, p. 96.

De Toni, A. a. (2001). Performance measurement systems: models, characteristics and measures. *International Journal of Operations and Production Management*, Vol. 21 Nos 1/2, pp. 46-70.

Dixon, J. R. (1990). The new performance challenge-measuring operations for world class competition. *IL: Dow Jones-Irwin*. Homewood.

Ellinger, A. E. (2000). Improving marketing/logistics cross functional collaboration in the supply chain. In *Industrial Marketing Management* pp. 29, 85–96.

Ellram, L. (1999). The supplier selection decision in strategic partnerships. *International Journal of Purchasing and Materials Management*, Vol. 26, No. 4, pp. 8–14.

Ferdows, K. a. (1990). Lasting improvements in manufacturing performance: in search of the new theory. *Journal of Operations Management*, Vol. 9, pp. 168–184.

Fergueson, B. R. (2000). Implementing supply chain management. *Production and Inventory Management Journal*, 64–67.

Flynn, B. a. (2004). An exploratory study of the nature of cumulative capabilities. *Journal of Operations Management*, Vol. 22, pp. 439–457.

Flynn, B. a. (2005). Synergies between supply chain management and quality management: emerging implications. *International Journal of Production Research*, Vol. 43 No. 16, pp. 3421-36.

Fynes, B. d. (2005). Supply chain relationship quality: the competitive environment and performance. *International Journal of Production Research*, Vol. 43 No. 16, pp. 3303-20.

Garvin, D. A. (1988). Managing Quality: the strategic and Competitive Edge. *New York: Free Press; London: Collier Macmillan,c1988*

Globerson, S. (1985). Issues in developing a performance criteria system for an organization. *International Journal of Production Research*, 23(4), 639–646.

Goulden, C. a. (1995). A hybrid model for process quality costing. *International Journal of Quality and Reliability Management*, Vol. 12 No. 8, p. 32.

Gunasekaran A., K. B. (2007). Performance measures and metrics in logistics and supply chain management: A review of recent literature (1995–2004) for research and applications. *Journal of Production Research*, 45(12): 2819–2840.

Gunasekaran, A. P. (2001). Performance measures and metrics in a supply chain environment. *International Journal of Operations and Production Management*, Vol. 21 Nos 1-2, pp. 71-87.

Gunasekaran, A. P. (2001). Performance measures and metrics in a supply chain environment. *International Journal of Operations & Production Management*, 21(1/2),71–87.

Gunasekaran, A. P. (2004). A framework for supply chain performance measurement. *International Journal of Production Economics*, Vol. 87 No. 3, pp. 333-47.

Gunter, C. S. (2006). Measuring supply chain performance: current research and future directions. *International Journal of Productivity and Performance Management*, Vol. 55 No. 3/4, pp. 242–258.

Hacker, M. a. (1998). *Designing and installing effective performance measurement systems.* IIIE Solutions

Handfield, R. B. (1999). *Introduction to supply chain management.* New Jersey: Prentice Hall

Hans-Jörg Bullinger, M. K. (2002). Analysing supply chain performance using a balanced measurement method. *International Journal of Production Research*, 40:15, 3533-3543.

Hieber, R. (2002). Supply Chain Management: A Collaborative Performance Measurement Approach. Zurich

Huang, S. S. (2004). A review and analysis of supply chain operations reference (SCOR) model. *Supply Chain Management: An International Journal*, Vol. 9 No. 1, pp. 23-9.

Huang, S. S. (2005). Computer assisted supply chain configuration based on supply chain operations reference (SCOR) model. *Computers and Industrial Engineering*, Vol. 48 No. 2, pp. 377-94.

Hudson, M. L. (2001). *Improving control through effective performance measurement in SMEs.* Production Planning and Control

Hudson, M. S. (2001). Theory and practice in SME performance measurement systems. *International Journal of Operations & Production Management*, Vol. 21 No. 8, pp. 1095-115.

Ing-Long Wu, C.-H. C. (2012). Using the balanced scorecard in assessing the performance of e-SCM diffusion:A multi-stage perspective. *Decision Support Systems*, 52,474–485.

Ing-Long Wu, C.-H. C. (2012). Using the balanced scorecard in assessing the performance of e-SCM diffusion:A multi-stage perspective. *Decision Support Systems*, 52, 474–485.

Kannan, V. a. (2005). Just in time, total quality management, and supply chain management: understanding their linkages and impact on business performance. *Omega*, Vol. 33, pp. 153 – 162.

Kaplan R.S., N. D. (1996). Linking the balanced scorecard to strategy. *California management review*, (1): 53–79.

Kaplan, R. a. (1996, January/February). Using the balanced scorecard as a strategic management system. *Harvard Business Review*, pp. 75-85.

Kaplan, R. S. (1992). The balanced scorecard: measures that drive performance. *Harvard Business Review*, 70(1), 71–9.

Keegan, D. P. (1989). Are your performance measures obsolete? In *Management Accounting* pp. 134–147.

Kennerley, M. &. (2002). A framework of the factors affecting the evolution of performance measurement systems. *International Journal of Operations & Production Management*, 22(11), 1222–1245.

Kennerley, M. &. (2003). Measuring performance in a changing business environment. *International Journal of Operations & Production Management*, 23(2), 213–229.

Kuo-Pin Chang, G. G. (2010). E-Business Strategy for Supply Chain Integration:The Balanced Scorecard Perspectives. *2010 International Symposium on Computer, Communication, Control and Automation*, pp. 480-483.

Li, S. S.-N.-N. (2005b). Development and validation of a measurement instrument for studying supply chain management practices. *Journal of Operations Management*, 23, 618–641.

Lockamy, A. &. (2004). Linking SCOR planning practices to supply chain performance: An exploratory study. *International Journal of Operations & Production Management*, 24(11–12), 1192–1218.

Lohman C., F. L. (2004). Designing a performance measurement system: A case study. *European Journal of Operational Research*, 156(2): 267–286.

Malmi, T. (2001). Balanced scorecards in Finnish companies: A research note. *Management Accounting Research*, 12, 207–220.

McCunn, P. (1998). *The balanced scorecard: the eleventh commandment.* Management Accounting

Mee, L. a. (1998). *The ten commandments of balanced scorecard implementation.* Management Control and Accounting

Meekings, A. (1995, October-December). Unlocking the potential of performance measurement: a guide to practical implementation. *ublic Money & Management*, pp. pp. 1-8.

Milind Kumar Sharma, R. B. (2007). An integrated BSC-AHP approach for supply chain management evaluation. *MEASURING BUSINESS EXCELLENCE*, VOL. 11 NO. 3.

Morgan, C. (2004). Structure, speed and salience: performance measurement in the supply chain. *Business Process Management Journal*, 10(5), 522–536.

Neely A., M. J. (1994). Realizing strategy through measurement. *International Journal of Operations & Production Management*, 14(3): 140–152.

Neely, A. G. (1995). Performance measurement systems design: a literature review and research agenda. *International Journal of Operations & Production Management*, 15(4), 80–116.

Norreklit, H. J. (2008). Pitfalls in using the balanced scorecard. *Journal of Corporate Accounting & Finance*, Vol. 19 No. 6, pp. 65-8.

Nudurupati, S. a. (2005). Implementation and impact of IT-supported performance measurement systems. *Production Planning and Control*, Vol. 16 No. 2, pp. 152-62.

Rajat Bhagwat a, M. K. (2007). Performance measurement of supply chain management: A balanced scorecard approach

Schneiderman, A. (1999). Why balanced scorecards fail. *Journal of Strategic Performance Measurement*, pp. 6-11.

Scho¨nsleben, P. (2004). *Integral Logistics Management: Planning and Control of Comprehensive Supply Chains.* St Lucie Press

Shepherd, C. a. (2006). Measuring supply chain performance: current research and future directions. *International Journal of Productivity and Performance Management*, Vol. 55, No. 3/4, p. 242.

Sillanpää. (2010). Supply chain performance measurement in the manufacturingindustry. A single case study research to develop a supply chain performance measurement framework. *University of Oulu. Acta Univ. Oul. C*, 374, 2010.

Stephens, S. (2001). Supply chain operations reference model version 5.0: a new tool to improve supply chain efficiency and achieve best practice. *Information Systems Frontiers*, 3(4), 471–476.

Thomas, J. (1999). *Why your supply chain doesn't work.* Logistics Management and Distribution Report

Waal, D. (2003). *Behavioral factors important for the successful implementation and use of performance management systems* (Vols. 41(8): 688–697). Management Decision

Waggoner, D. B. (1999). The forces that shape organisational performance measurement systems: An interdisciplinary review. *International Journal of Production Economics*, 60/61, 53–60.

Webster, M. (2002). Supply system structure, management and performance: a conceptual model. *International Journal of Management Reviews*, 4(4), 353–369.

Wood, S. J. (2004). Revisiting the use and effectiveness of modern manufacturing practices. *Human Factors & Ergonomics in Manufacturing*, 14(4),415–32.

Appendix

Figure 1:

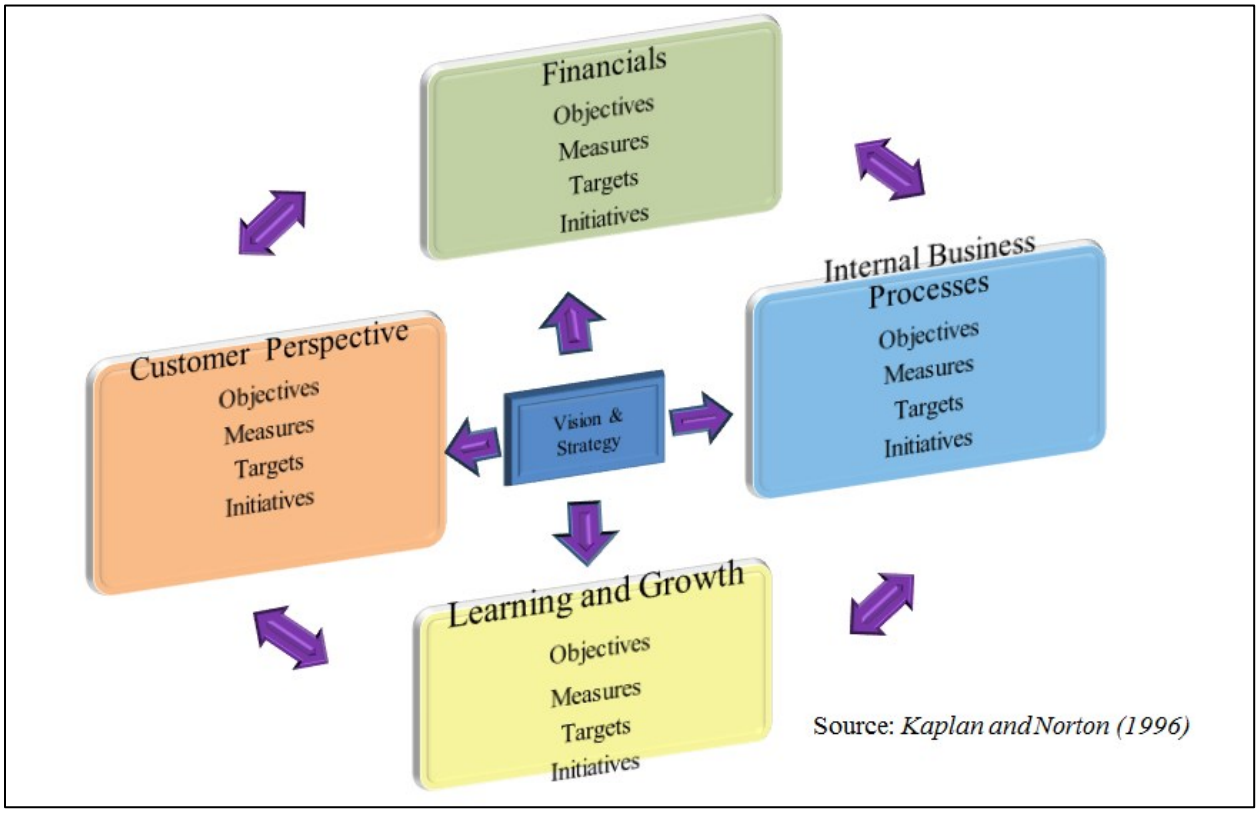


Figure 2:

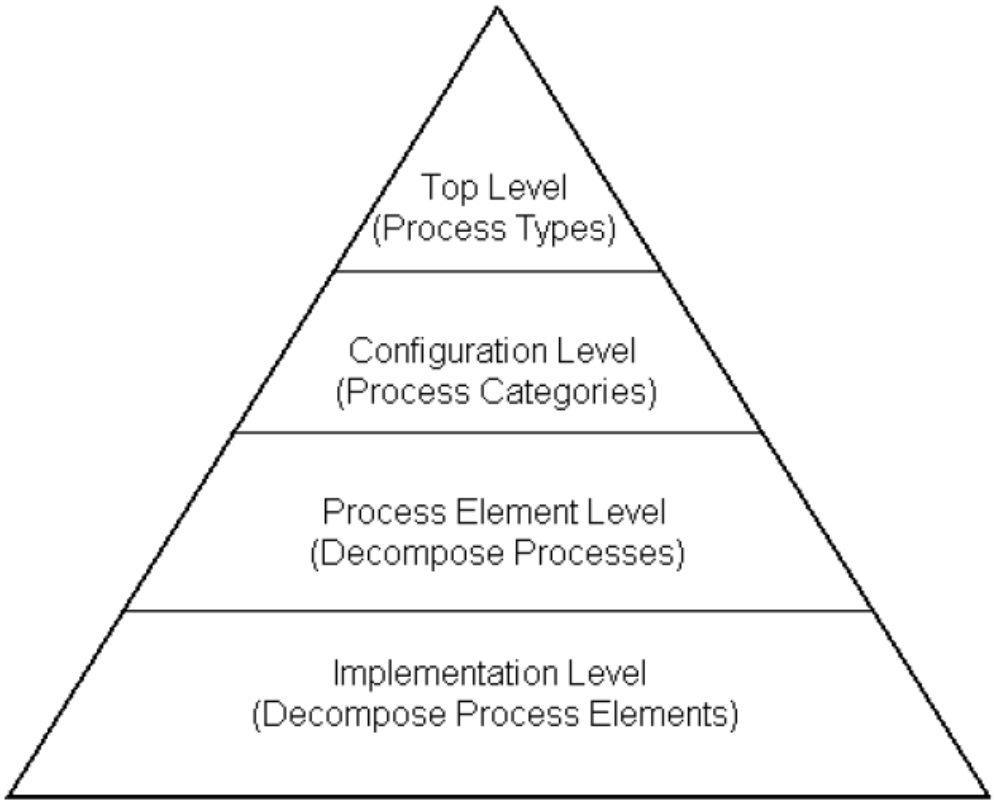
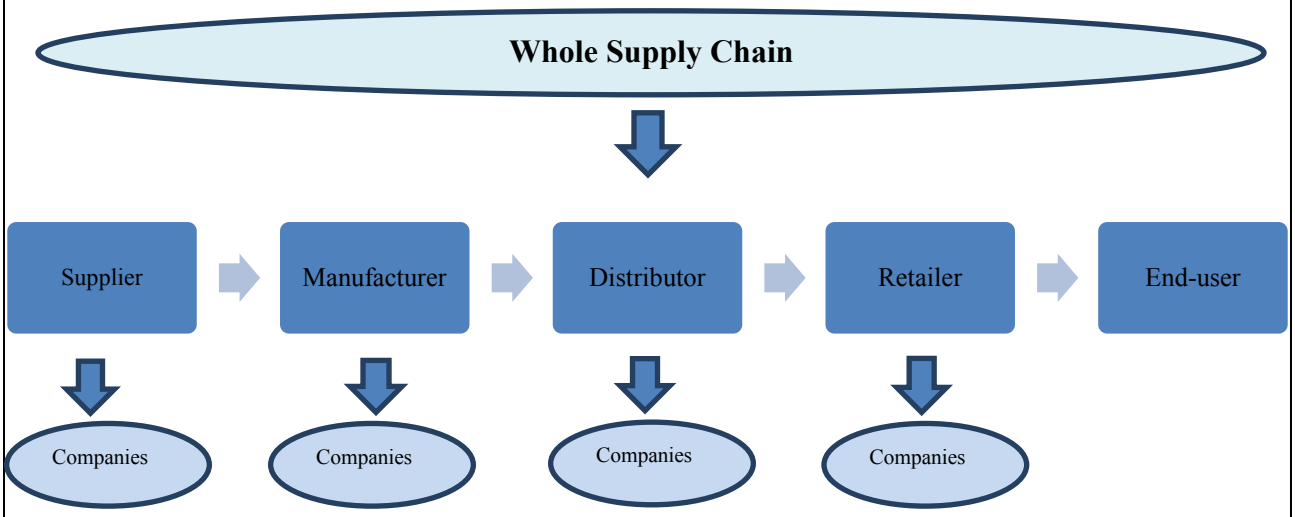


Figure 4. Supply Chain Operations Reference Model

(source: Based on www.supply-chain.org)

Questionnaire of Performance Measurement of Manufacturing Supply Chain

Typical five organizations of a whole supply chain:



SC: Supply Chain

As indicated in the figure above, please pay attention that this questionnaire is based on the whole SC which includes your company. It is not based on your company's SC. If your company has headquarters and branches, please consider the one you are currently working in.

Please notice that this questionnaire is highly confidential. We will not release your information to any other third party without your permission. By responding to the questionnaire you will get an opportunity to be a randomly selected respondent who will win a mini iPad!

Part 1: Demographic Information

Please tick the option(s) you choose and (or) fill out blanks if indicated:

No.	Question		
1.	Your company's industry is	☐ Electronics ☐ Food ☐ Beverage ☐ Textile ☐ Mechanical ☐ Aerospace ☐ Chemical ☐ Metallurgy	☐ Automotive ☐ Pharmaceutical ☐ Construction ☐ Logistics Other(s), please specify ----------
2.	Your company location is	Please specify which country ----------	
3.	Number of employees in your company is	☐ Less than 50 ☐ 50 – 100 ☐ 101 – 250 ☐ 251 – 500 ☐ 501 – 1000	☐ 1001 – 2500 ☐ 2501 – 5000 ☐ 5001 – 10000 ☐ 10001 – 50000 ☐ 50001 – 100000 ☐ 100001 and above
4.	Annual sales of your company is (in U.S. dollars)	☐ Less than 1 Million ☐ 1 – 5 Million ☐ 6 – 25 Million ☐ 26 – 50 Million	☐ 51 – 100 Million ☐ 101 – 250 Million ☐ 251 Million – 1/2 Billion ☐ 1/2 Billion and above
5.	Your department is	☐ Production ☐ Quality Control ☐ Technical Support ☐ Logistics ☐ HR ☐ Finance	☐ Marketing ☐ Sales ☐ R&D ☐ Sourcing ☐ Supply Chain Other(s), please specify ----------
6.	Your company's role in SC is	☐ Supplier ☐ Transporter ☐ Manufacturer ☐ Distributor	☐ Wholesaler ☐ Retailer ☐ Customer Other(s), please specify ----------

7.	Your current position is	☐ Owner ☐ General Manager ☐ Manager ☐ Supervisor ☐ Project Leader/Manager ☐ Buyer Other(s), please specify ----------	
8.	Your working experience in this position is	☐ Less than 1 year ☐ 1 - 2 years ☐ 2 - 3 years ☐ 3 - 4 years	☐ 4 - 5 years ☐ 5 - 10 years ☐ 10 - 15 years ☐ More than 15 years
9.	Does the whole SC have any strategic alliance?	☐ Yes	☐ No
10.	If 'Yes', please choose organizations belonging to the strategic alliance	☐ Supplier ☐ Transporter ☐ Manufacturer ☐ Distributor	☐ Wholesaler ☐ Retailer ☐ Customer Other(s), please specify ----------
11.	Is the whole SC all within the same country?	☐ Yes	☐ No
12.	If 'No', which organization(s) is (are) out of your country?	☐ Supplier ☐ Transporter ☐ Manufacturer ☐ Distributor	☐ Wholesaler ☐ Retailer ☐ Customer ☐ End-user Other(s), please specify ----------

13.	Numbers of suppliers, manufacturers, distributors, retailers and customers in the whole SC	Suppliers ☐ I don't know ☐ 1-10 ☐ 11-50 ☐ 51-100 ☐ 101-200 ☐ 201-300 ☐ 301-400 ☐ 401-500 ☐ 501-600 ☐ 601-700 ☐ 701-800 ☐ 801-900 ☐ 901-1000 ☐ 1001 and above	Manufacturers ☐ I don't know ☐ 1- 5 ☐ 6-10 ☐ 11-20 ☐ 21 and above	Distributors ☐ I don't know ☐ 1-10 ☐ 11-50 ☐ 51-100 ☐ 101-200 ☐ 201-300 ☐ 301-400 ☐ 401-500 ☐ 501 and above ☐ N/A	Retailers ☐ I don't know ☐ 1-10 ☐ 11-50 ☐ 51-100 ☐ 101- 200 ☐ 201-300 ☐ 301-400 ☐ 401-500 ☐ 501-600 ☐ 601-700 ☐ 701-800 ☐ 801-900 ☐ 901-1000 ☐ 1001 and above ☐ N/A	Customers ☐ I don't know ☐ 1-10 ☐ 11-50 ☐ 51-100 ☐ 101- 200 ☐ 201-300 ☐ 301-400 ☐ 401-500 ☐ 501-600 ☐ 601-700 ☐ 701-800 ☐ 801-900 ☐ 901-1000 ☐ 1001 and above ☐ N/A

Part 2: General Information

Please tick the option(s) you choose after each question and (or) fill out blanks if indicated:

General Information						
No.	**Question**	**1 Strongly Disagree**	**2**	**3**	**4**	**5 Strongly Agree**
1.	Performance measurement is important in the whole SC					
2.	Have you implemented any kinds of performance measurement system(s) in the whole SC?	☐ Yes ☐ No				
3.	If 'Yes', please choose performance measurement system(s) which has (have) been implemented in the whole SC?	☐ Balanced Scorecard ☐ Total Quality Management ☐ Supply Chain Operations Reference Other(s), please specify ----------				
4.	Which aspect of the whole SC is the most important to measure? (Please only tick one option or fill it out)	☐ Time ☐ Flexibility ☐ Reliability ☐ Cost Other, please specify ----------				

5.	What is (are) the main reason(s) which prevent(s) the whole SC from implementing performance measurement system(s)?	☐ Cost ☐ Manpower ☐ Time ☐ Lack of data ☐ Lack of interest	☐ Lack of management commitment ☐ Lack of priority among projects ☐ Lack of knowledge ☐ N/A Other(s), please specify ----------

Part 3: Importance of attributes

Please tick the level of importance of the following attributes in the whole SC:

Resource							
No.	**Attributes**	**1** Unimportant	**2** Slightly important	**3** Important	**4** Highly important	**5** Critically important	**N/A**
1.	Minimization of cost						
2.	Minimization of waste						
3.	Environmental friendliness						
4.	Efficient utilization of resources						

Customer-based Interaction							
No.	**Attributes**	**1** Unimportant	**2** Slightly important	**3** Important	**4** Highly important	**5** Critically important	**N/A**
5.	Fulfill rate						
6.	Warranty return rate						
7.	Number of shipping errors						
8.	Number of successful on time deliveries						

No.	Attributes	1 Unimportant	2 Slightly important	3 Important	4 Highly important	5 Critically important	N/A
9.	Impact of power on business relationship						
10.	Implementation of customer's future strategic needs						
11.	Customer satisfaction						
12.	Customer loyalty						

SC-based Interaction							
No.	**Attributes**	**1 Unimportant**	**2 Slightly important**	**3 Important**	**4 Highly important**	**5 Critically important**	**N/A**
13.	Uniformity of systems within the company						
14.	Uniformity of systems among the organizations						
15.	Information sharing capability within the company						
16.	Information sharing capability among the organizations						
17.	Trust within the company						
18.	Trust among the organizations						
19.	Coverage of organizations in strategic alliance						

Flexibility							
No.	**Attributes**	**1** Unimportant	**2** Slightly important	**3** Important	**4** Highly important	**5** Critically important	**N/A**
20.	Flexibility in production volume						
21.	Flexibility in time of delivery						
22.	Flexibility in changing the variety of products produced						
23.	Flexibility in introducing new products						

Part 4: Status of Attributes

Now please evaluate the status of the following attributes in the whole SC. (How well is the whole SC doing in terms of each attribute?) Tick the most appropriate status:

Resource								
No.	**Attributes**	**1** Worst status	**2**	**3**	**4**	**5** Best status	**I don't know**	**N/A**
1.	Minimization of cost							
2.	Minimization of waste							
3.	Environmental friendliness							
4.	Efficient utilization of resources							

Customer-based Interaction								
No.	**Attributes**	**1** Worst status	**2**	**3**	**4**	**5** Best status	**I don't know**	**N/A**
5.	Fulfill rate							
No.	**Attributes**	**1** Worst status	**2**	**3**	**4**	**5** Best status	**I don't know**	**N/A**

6.	Warranty return rate							
7.	Number of shipping errors							
8.	Number of successful on time deliveries							
9.	Impact of power on business relationship							
10.	Implementation of customer's future strategic needs							
11.	Customer satisfaction							
12.	Customer loyalty							

SC-based Interaction								
No.	**Attributes**	**1 Worst status**	**2**	**3**	**4**	**5 Best status**	**I don't know**	**N/A**
13.	Uniformity of systems within the company							
14.	Uniformity of systems among the organizations							
15.	Information sharing capability within the company							
16.	Information sharing capability among the organizations							
17.	Trust within the company							
18.	Trust among the organizations							
19.	Coverage of organizations in strategic alliance							

Flexibility								
No.	**Attributes**	**1 Worst status**	**2**	**3**	**4**	**5 Best status**	**I don't know**	**N/A**
20.	Flexibility in production volume							
21.	Flexibility in time of delivery							
22.	Flexibility in changing the variety of products produced							
23.	Flexibility in introducing new products							

Thanks for your time, please tick the option you choose		
Are you interested in receiving the research summary?	☐ **Yes**	☐ **No**
Do you want to be included in the draw to win the mini iPad?	☐ **Yes**	☐ **No**
If you ticked 'Yes' in any of the two questions, please leave your email address here		